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SOCIETY OF ENGINEERS.

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PLACE OF MEETING AND OFFICES:

THE SOCIETY'S HALL, No. 6, WESTMINSTER CHAMBERS,
VICTORIA STREET, WESTMINSTER.

LONDON:
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NEW YORK:
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REMOTE STORAGE

PREMIUMS FOR 1879.

At a meeting of the Society, held on February 2nd, 1880, a Premium of Books was awarded to:

CHARLES J. ALFORD, for his paper on "The Mineralogy of the Island of Sardinia."

And to:

THOMAS ANDREWS, for his paper on "The Strength of Wrought-iron Railway Axles."

G Feb. 1917, McElroy

355346

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SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

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Vice-Presidents.—JOSEPH BERNAYS. CHARLES HORSLEY. THOMAS PORTER.

CLEMENT BARNARD.
JABEZ CHURCH.
SAMUEL CUTLER.
FREDERIC E. DUCKHAM.
FREDERICK W. HARTLEY.
ARTHUR RIGG.
WILLIAM SCHÖNHEYDER.
JOHN WALKER.

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PLACE OF MEETING AND OFFICES:

THE SOCIETY'S HALL, 6, WESTMINSTER CHAMBERS, VICTORIA STREET, S.W.

1880.

TRANSACTIONS, &c.

February 3rd, 1879.

INAUGURAL ADDRESS.

By ROBERT PAULSON SPICE, President.

When, a year since, I first addressed you as your newly elected President, the probability of my having to do so a second time under similar circumstances never for one moment presented itself to my imagination. My year of office, however, passed by, and at its close you did me the unmerited honour of electing me a second time to the presidential chair, thereby conferring upon me a distinction of which I can unaffectedly say I am truly proud. Such a distinctive mark of your approbation has, I am aware, been before bestowed on some of my predecessors. The rarity of the occurrence, however, greatly enhances the honour conferred, and should lead its recipient to ask himself why he has been selected for the reception of such a high testimonial at your hands. For my own part, a retrospective glance at my year of office just closed, only reveals to me several shortcomings which, in the interests of the Society, I would that I had not to record. But we are not the arbiters of our own destinies, and when, a year ago, I entered upon my duties as your President, with a full determination to allow nothing to intervene between myself and those duties, I little thought that before the year closed I should have cause to recognize the truth of that aphorism which teaches us that man proposes but that a Higher Power than that of man disposes. But so it has been with me: ill-health in the latter part of the year intervened to prevent my attending so constantly to my presidential duties as I otherwise should, and deprived me of the pleasure—for it always is a pleasure to me—of attending some of our vacation visits and our meetings. I am aware, however, that at such times my place was most efficiently filled by one or other of my colleagues upon the Council, and that, through their kindness, the interests of the Society in no way

suffered by my enforced absence. To those gentlemen who have so kindly undertaken to discharge the presidential duties upon those occasions, I beg to return my sincere thanks. Their willing co-operation and able support relieved me from any anxiety I might otherwise have experienced. Seeing then that I have not so perfectly fulfilled the duties of my office as I should have done and as I wished to do, I am at a loss to account for the circumstance of my having again been honoured with your kind suffrages. However, I can but thank you most sincerely for electing me a second time to the presidential chair, and I trust I may accept the honour done me as a token of approval on your part of the slender services I have been able to render our Society, in which I feel a warm personal interest. Having in the year that is passed experienced your considerate indulgence and support as well as the cordial co-operation of my fellow-members of Council, I need not say that I am greatly encouraged in entering upon my second term of office, and when that term shall have expired, I trust that the confidence you now repose in me will be found to have been in no way misplaced.

A year ago, notwithstanding the general depression of commercial and manufacturing interests, I was able to congratulate the members upon the satisfactory position of our Society. It is very gratifying to me to be able to repeat those expressions of satisfaction, for although our numerical strength has not increased so greatly during the past as it did during the previous year, we have still made a fair addition to our numbers, and in spite of our having passed through as bad, or even worse, times, our financial position and prospects are satisfactory. Death, however, has unfortunately deprived us of some members, whilst others have, for one reason or another, retired from the Society. To fill these vacancies and to preserve a good muster roll, I would ask our friends, present and absent, to use their best exertions to introduce new members, and so to maintain the *status* of our Society.

I have said that death has again been busy in our midst, and I regret having to announce the decease of no fewer than eight of our members during the past year. The first taken from among us was Mr. Alexander James Bridge, who was elected in 1871, and died on the 2nd of January, 1878. The next was Mr. William Thomas Carrington, an old member and a past President of our Society, who was elected a member in 1858, was President for the year 1865, and died on the 21st of March last. Mr. Carrington had a wide and varied experience both as a civil and a mechanical engineer, and at the time of his death

was the municipal engineer at Singapore, which appointment he had held for several years previously. When in England, he always took an active interest in the affairs of our Society, of which he was a deservedly popular member. The next death was that of Mr. William C. Watson, who was elected in 1871, and died at Montevideo on the 6th of May, holding at the time the appointment of resident engineer to the Montevideo Gas Company. Mr. John Ashdown, civil engineer, was elected in 1873, and died on the 26th of August. On the 23rd of September death deprived us of one of our most esteemed honorary members, Mr. John Penn, whose name is so inseparably connected with the progress and development of marine engineering, and to whom I shall again refer. In the same month there died also one of our foreign members, M. José Santiago Camacho, who was only elected the year previously. Mr. William A. Lyttle, who was connected with the telegraphic department of the Post Office, and was elected in 1867, died on the 23rd of October. Lastly, on the 10th of December, we lost Mr. Samuel Herbert F. Cox, a mining engineer, practising in Cornwall, who was elected in 1865.

Before quitting the subject of death's doings, I would place on record a few of the leading facts pertaining to the life of that distinguished mechanician John Penn, who, as I have already said, honoured our Society by becoming one of its honorary members. Mr. Penn was born in 1805, at Greenwich, where his father had been established for many years as a millwright and engineer. He entered his father's works at an early age, and became their possessor in 1843, on the death of his father. One of Penn's earliest productions was the grasshopper engine, the first of that type having been fitted up at his father's works, and being in fact the first engine there used. He next designed a table engine with a 10-inch vertical cylinder, which is still in use at the factory at Greenwich. The earliest marine engines designed and built by Mr. Penn were, I believe, those with which the steamers 'Ipswich' and 'Suffolk' were fitted. These vessels were built for traffic on the river Orwell, and the engines were of the beam type and of 40 horse-power. Mr. Penn reproduced these engines, with certain modifications, for four passenger boats which were built in 1835 for the Thames, and which ran between London and Greenwich. The oscillating cylinder was the next object of Mr. Penn's attention. As originally arranged it was very imperfect, but he mastered the difficulties which beset the question so thoroughly that he made the oscillating engine a success. This important development in marine engineering was first introduced by

Mr. Penn into the Admiralty yacht 'Black Eagle,' in 1844. The successful results of this application of the principle led to the speedy adoption of this class of engine in numerous Government and other steamships. Mr. Penn's next step was the introduction of trunk engines into vessels of war propelled by the screw. By this arrangement he was enabled to place the engines low, and consequently in comparative safety, and at the same time to drive the screw propeller direct. Down to the time of Mr. Penn's death his firm had fitted 230 vessels of all classes with trunk engines. Altogether they had then engined 735 vessels, representing in the aggregate 500,000 actual horse-power, and including the principal vessels of the British Royal Navy. Another important detail of marine engineering with which Mr. Penn's name is identified is that of the sea-bearings of screw propellers. In the early days of screw propulsion great difficulty was experienced in obtaining a suitable material for this purpose. After an exhaustive investigation of the subject, during which he made many hundred experiments in conjunction with Mr. Francis Pettit Smith, Mr. Penn finally resolved upon the application of *lignum vitæ* for the sea-bearings of screw shafts. The first practical application proved wood bearings to be a perfect success, and the introduction of the system soon became general, thus rendering practicable the system of screw propulsion in large as well as in small vessels, which previously had stood in jeopardy of abandonment in connection with vessels of the former class. Although Mr. Penn retired from the more active duties of his business several years since, he still continued to evince great interest in engineering pursuits, and to the last he retained that clear judgment and fine perception of what was practicable in marine engineering for which he had been essentially distinguished through his long, honourable, and useful career.

From those who have ceased to move in our midst let me turn to some of those who are still with us, and who during the past year have practically manifested their interest in the Society in the most valuable manner they could, namely, by kindly preparing and reading papers at our meetings. To those gentlemen, the Society as a body owes a special debt of gratitude, and I much wish there were more who would endeavour to increase that debt, for I can assure you we much need some good, short, practical papers. I do trust that at the close of the year upon which we are now entering the Council may not have to regret the general reticence of members in this respect as they have had in the year just closed. During the year we have had seven papers read, all of which have led to

interesting and sometimes valuable discussions. Taken as a whole, however, these productions scarcely rank so high in the order of merit as those of many previous years. In saying this, I would by no means discourage those who have given us their help in this direction in the past from assisting us again if they will kindly do so, nor would I alarm any one of those who may be contemplating the preparation of a paper for reading before the Society. On the contrary, I trust that my observations may encourage and stimulate all to renewed exertions on behalf of our contributions as a body to the literature of our profession, and so to increase the good repute of our Society.

Of the seven papers to which I have referred, the first was by Mr. J. W. Pearse, on water purification, sanitary and industrial. The sanitary aspect of water purification was fully treated, and we had all the various systems of filtration placed before us. The subject, however, was not very fully treated as regards what to this Society is the far more important aspect of the question, the industrial, inasmuch as M. Le Tellier's hydrometric purifier, was the only apparatus introduced to our notice bearing on the subject of the paper as regards the arts and manufactures. Mr. Pearse, however, who had previously read several useful practical papers before the Society, led us to hope for further information upon the second part of his subject at some future time, and I trust that this hope will be realized.

The second paper was by Mr. W. Schönheyder, an old member of our Society, and who has been elected a member of our Council for the present year. Mr. Schönheyder's paper was on equalizing the wear in horizontal steam-cylinders, and he explained that one objection to this form of engine, was the great and unequal wear of the cylinder, which is due to the weight of the piston continually rubbing backwards and forwards on it. After enumerating the evils resulting from the unequal wear of cylinders and pistons, and describing the most important expedients for preventing this action, Mr. Schönheyder placed before us particulars of his own ingenious invention for remedying the evil. This consists in making the piston rod with a camber in such a manner as that when loaded with the weight of the piston and placed in the cylinder, it assumes a straight line, and transfers the weight to the outside guides. Mr. Schönheyder also described the special tools which he had designed for rendering the production of these rods easy and certain.

The next paper was on modern roadway construction, by Mr. Henry S. Copland, and was by far the best we had during the year, and will compare favourably with any ever read before the Society. The author showed great practical research,

and a thorough knowledge of his subject, and although he had to advance the merits of a system of roadway construction of his own in the face of those of other systems, he did so with the greatest fairness, and never advanced other than practical reasons against systems competing with his own. Mr. Copland took us back some centuries in the history of road making, noticing the progress made by the various nations of antiquity, the state of decay into which mediæval roads had been allowed to fall, and the various attempts made to improve them since the commencement of the present century. He then described the principal systems of roadway construction at present in use, and pointed out the extent to which he considered they met or failed to meet the requirements of a good modern roadway. He then explained the principles upon which, with a view to avoiding the defects of previous systems, he had designed his asphaltic wood pavement, which is gradually coming into use for roadways. Mr. Copland finally placed before us details of the expenses attending the construction and maintenance of the various systems of roadway, and in opening the adjourned discussion which took place on his paper, he gave the Society some valuable particulars with regard to steam rolling. The merits of Mr. Copland's paper were recognized by the Council awarding to its author the first premium.

The lighting and extinction of gas lamps by means of electricity formed the subject of the next paper, which was read by Mr. St. George Lane Fox, and in which that gentleman explained the ingenious device by which he effects that object. In his system the lamps are connected together with an insulated wire, so that electric impulses sent from a station will operate simultaneously on every lamp in the circuit through the instrumentality of an apparatus with which each lamp is provided, so as to turn the gas on or off, and also to light it. The lamp apparatus consists chiefly of a small induction coil, which produces the spark for lighting the gas at the burner, and the soft iron cone of this coil supplies, in conjunction with a permanent magnet, the necessary power for opening and closing a specially-constructed valve. Mr. Fox demonstrated the practicability of his invention in this room. The system was applied in a temporary manner to fifty-five street lamps in Pall Mall and some of the adjoining streets, and for some time the lamps were regularly turned on, lighted, and turned off by electricity, with, I am informed, a fair amount of success. This system, however, has been discontinued for some time past, for what reason I cannot say, except perhaps partly in view of the improved form

of illumination which is being introduced in that neighbourhood. Highly ingenious as is Mr. Fox's system, it appears to me upon careful consideration to be rather more practicable than practical—at least, in its present shape.

Mr. George G. André followed with a useful paper on the application of electricity to quite another purpose, namely, that of the ignition of blasting charges. Mr. André has had considerable experience in mining operations underground, and is well qualified to deal with this question. He told us that the advantages afforded by electrical firing were those due to the simultaneous discharge of the blasts and those resulting from the nature of the means of ignition. Electrical firing affords increased safety to the miners, who often lose their lives through the unexpected explosion of charges which have been approached by the men under the conviction that they had missed fire through a defect in the ordinary fuse. Mr. André stated the requirements which a good electric fuse should fulfil, pointed out the shortcomings of the tension fuses now in use, which he appears to have remedied in an electrical fuse of his own construction, with which he experimented before us. The paper was considered by the Council to be of a sufficiently practical and useful nature to entitle its author to a premium, which they awarded him.

An interesting communication on harbour bars, their formation, and removal, was next made to the Society by Mr. Henry F. Knapp, of New York. Mr. Knapp theorized considerably upon the cause of the formation of bars and shoals, and placed before us a proposition to destroy them by interfering with wave action. He proposes to construct a barrier directly across the mouth of a river or harbour, outside the natural bar, and having a good depth of water over it. This barrier, we were told, would, on the theory of interference to wave action, destroy the building-up power of the waves, and would leave unimpaired the full force of the river to cut out the bar. The theory is a seductive one to deal with on paper, but would, I fear, prove illusory if attempted to be put to the test of practice.

The last paper of the year was an apparatus for utilizing the waste heat of exhaust steam, or, in other words, on feed-water heaters, by Mr. James Atkinson, who explained to us the different kinds of apparatus in use for this purpose, including one of his own designing, which has several meritorious features, and appears to be doing well in practice. There can be no doubt that it is of great importance that the feed water supplied to steam boilers should have its temperature raised as highly as

possible by means of the waste heat from the exhaust steam. A considerable saving in fuel may be effected by the use of an efficient heater, and the durability of the boiler increased.

Such are the papers we had during last year; and, if you have been able to follow me in my necessarily brief and rapid *résumé*, you will, I feel assured, agree with me that the standard falls somewhat below the average of recent years; and I trust we have those among us who will bestir themselves to raise that standard during the present year. I am quite aware of the demands on the time of professional men, which, in my own case, seem to increase as years go on. But I am equally well aware that there are some amongst us who could help us in this direction if they would. Naturally enough, those who have never essayed to read a paper may have their doubts and fears as to success; but let them only grapple with the difficulty as they would with an engineering problem, and they would inevitably surmount it, and would benefit themselves as well as the Society by the exercise. I will now quit this subject, which I might not have pressed upon you so strongly, did I not know that the vitality of an institution like ours depends largely upon the quantity, but mainly upon the quality of its papers.

Following what has now become a time-honoured custom with us, the Society made several visits to engineering and other works of professional interest, during the vacation of 1878. Those visits were well attended, and, as usual, proved both interesting and instructive, and did not fail to commend themselves to those seeking practical information on professional subjects. We made four visits in all, the first being to the Lambeth pottery works of Messrs. Doulton and Co., where the manufacture of pottery was witnessed in all its varied stages. From Messrs. Doulton's we made our way to the celebrated establishment of Messrs. Maudslay, Sons, and Field, in Lambeth, where, amongst other things, we were able to inspect some fine examples of marine engines which were being made for two of our ironclad ships. The day's work was concluded by a visit to the goods depôt of the London, Chatham, and Dover Railway at Blackfriars, where the members inspected the hydraulic machinery and the underground arrangements for carrying on the extensive goods traffic at that station.

Our second visit was to the works of the Victoria Dock Extension, where we were kindly received by Mr. A. C. Andros, the resident engineer (for Mr. A. M. Rendel, the engineer of the works), and by that gentleman and Mr. Colson, the engineer for Messrs. Lucas and Aird, the contractors, we were conducted over the works. As I described these works in my Address to

you last year, I need not further refer to them here, nor to our pleasant visit, which was made most agreeable by the hospitable reception Messrs. Lucas and Aird accorded to us.

Our third visit was to the magnificent pile of buildings now in course of erection for the New Law Courts, which were inspected with much interest. From thence the members went to the engineering works of Messrs. Pontifex and Wood, in Shoe Lane, where they had the opportunity of seeing the manufacture of brewing plant and machinery, as well as that of sheet lead and lead pipes. The members afterwards visited the works of our old member, Mr. Samuel Owens, in Whitefriars Street, where they were shown the manufacture of all kinds of pumps and hydraulic machinery.

The fourth and last visit of the vacation was made to Croydon, where the members were received and subsequently entertained at luncheon by our old and esteemed member and Past President, Mr. Baldwin Latham. The steam-clock factory of Messrs. Gillett and Bland was first inspected, and there the process of clock making in all its varied branches and that of bell founding were witnessed. The chief object of attraction was the new clock for the Manchester Town Hall, which was then nearly completed, and has since been placed in its intended position. The pumping station of the Croydon Waterworks was next visited, where one of Mr. Davey's compound differential pumping engines had then recently been erected. This engine is an excellent example of mechanical genius, and reflects great credit upon its designer, who is one of our members, and upon its manufacturers, Messrs. Hathorn Davey and Campbell, of Leeds, of which firm Mr. Davey is the second partner. After inspecting the pumping engines, we visited the sewage-extracting machinery designed by Mr. Latham, and which effectually separates the solid and insoluble compounds of sewage from the liquid; the latter flows on to the sewage irrigation farm at Beddington, which was finally inspected, and where the pure effluent water, no less than the splendid crops of grass, showed how thoroughly the sewage of the district was utilized.

It will be seen that the establishments visited were very varied in their character, thus affording to members practising in the various branches of the profession—and of which our Society is composed—the opportunity of inspecting works in which they take a special interest. The Council hope to arrange a programme of visits this year quite as varied as that of last, and thus to sustain the interest which has always been manifested by the members with regard to these vacation visits.

Having brought under your notice those matters which most

directly interest us as members of the Society of Engineers, I will now direct your attention to a few of the leading features which have marked the year so recently closed. Professionally speaking, these have been neither remarkable nor numerous, nor have they indicated any great scientific stride. This is probably due to the general depression which continued to hang over the year like a heavy cloud, which it was vainly hoped by some would roll away so soon as the political horizon in the East became clearer. But it did not move, even when "peace with honour" was proclaimed over the whole world. It is not usual for us to look into commercial questions, but there are times when an exception to this rule may be not only tolerated, but may be acceptable. Such a time, I take it, is the present, when commercial depression touches professional interests so directly, and when so many serious commercial disasters have occurred; and, before a healthy tone is re-established, still further calamities of a like nature may possibly supervene.

What are popularly known as "bad times" commenced in 1874, and the struggle against them has been continued down to the present time. Every important industry has felt the depression in an increasing degree; and prices have continued to shrink, dragging down wages with them, obliterating profits, and too often resulting in serious losses. One cause of the prevailing trade depression has undoubtedly been the gross and wide-spread abuse of the systems of credit which obtained some years since, and which brought into existence difficulties with which we, as a nation, have been wrestling ever since. Numerous civilized, and some uncivilized, countries endeavoured to outvie each other in the development of modern industries and scientific improvements, and that to a large extent with borrowed capital. This led, several years since, to a state of inflation, the reaction from which cannot yet be said to have subsided. It culminated, more or less, with the close of the year, the industrial disorganization having gone on increasing month by month, until at last the year closed amid the most depressing influences, and with doubts and fears on every hand. Matters, however, have assumed a slightly healthier aspect since the present year opened; and although I cannot discover any immediate signs of a return to our former prosperous condition, I see tranquillity somewhat restored, and I conceive, and earnestly hope, that the worst point has now been reached.

Before quitting this subject, and by way of confirmation of what I have just advanced, I will place before you a few statistics which will serve to indicate the extent to which the manufacturing industries of this country have suffered since 1874, by

the fall in prices alone. In doing so, I will take those products which, besides being the staple commodities of our country, are those with which every engineer has daily to deal in a more or less direct manner. I refer to iron and coal. In doing this, I will compare the prices which were current at the close of last year, with those of 1874. This will not be a strained comparison, inasmuch as although in the year 1874 signs of the reaction which has since overtaken us began to present themselves, they were not fully developed in that year. So far as values are concerned, the height of our export trade was reached in 1872, when we exported home produce and manufactures to the value of 256,257,000*l.* The highest import values, however, were not reached until 1877, so that the reaction has hitherto appeared to be only working one way. This discrepancy is partially accounted for by deficient harvests, but there are other reasons which have assisted, and into which I need not here enter. Turning to our old and special friends, iron and coal, I find the average declared value of pig iron in 1874 was about 95*s.* per ton, but for the eleven months of 1878, for which figures were published at the close of the year—and I need not go further—it had only been 53*s.* 6*d.* per ton, showing a falling off of about 44 per cent. Just before last Christmas, pig-iron warrants were quoted as low as 43*s.* 7*d.* per ton in Glasgow, and in the Cleveland district it would seem that iron could be produced at less than 35*s.* per ton. Coals necessarily experienced a proportionate fall, and thus the average declared value of the "coals, cinders, and fuel" exported at the close of the year was only about 9*s.* 6*d.* per ton, as compared with about 17*s.* 2*d.* in 1874. The products of other industries present corresponding features—worse, perhaps, in some cases—but I need not dwell longer on these facts, which speak but too plainly for themselves, and remind us also forcibly of what has been going on, with greater or less severity, in every department of business.

These, however, are not the only results, nor the causes which have led to them the only causes, which have combined and prevailed to produce the present state of depression in our commercial and manufacturing atmosphere. It cannot be concealed that some of the markets of the world formerly open to our merchants and manufacturers, have been virtually closed to us by the lamentable return in those countries to the old system of "protective duties," as they are called, the application of which to our manufactures amounts to the positive prevention of the people from continuing to be our customers, their statesmen, blind to the best and lasting interests of the masses, having

determined so to favour the few at the expense of the many, in utter disregard of the soundest principles of political economy.

Let us, however, instead of croaking, stand up and quit ourselves like men, and especially as becomes Englishmen; leaving the people of less favoured nations to wrap themselves up in the worn-out and threadbare vestments of "protection." We may be thankful that we, at all events, are not compelled by law to buy in the dearest market instead of the cheapest, and that whatever else we may have, we have colonies which, with one lamentable exception, where a retrograde policy has been attempted, are free from the taint of this bugbear, and that our trade with them is ever on the increase, to our mutual advantage. And we have the wide world open to us, vast portions of it waiting to be cultivated on sound commercial principles; notably Africa and China, with their untold millions of inhabitants, presenting boundless opportunities for the profitable employment of British enterprise and capital, and the skill of English engineers.

The most prominently interesting scientific feature of the year has undoubtedly been the experimental introduction of electric lighting, on a more or less practical scale, in London and other places. There can be no doubt that undue prominence has been given to the question of electric lighting generally, which at the time led to equally undue alarm in the minds of those who are interested as investors in undertakings for the production of artificial light from other sources. It is not my province here to inquire into the causes which led to that undue prominence, nor to the motives which influenced the getting up of what was very properly called a "scare." It is sufficient for me to state the fact, which indeed must have been patent to everyone who was able to think for himself, and capable of looking facts calmly in the face, as they presented themselves to him. What I propose to do, is to place before you particulars of such systems of electric lighting as have been introduced to public notice in a practical form during the past year, and to point out how far each has progressed towards practical utility.

In addressing you from this chair last year I pointed out that the advance of illumination by the electric light during the preceding year had been very slight indeed. The only system which had been tried on anything like a working scale, was that of M. Jablochkoff, with which some experiments were made in the West-India Docks during the preceding summer. So far as they went these experiments were satisfactory, although they revealed several defects which have since been remedied, and have rendered the invention better fitted for practical

purposes. I do not overlook the question of the cost of production, the consideration of which, however, I reserve for the present. The only other application of the electric light of a practical nature I then had to notice was that of its use in photography, the light having been successfully utilized for this purpose by Mr. Van der Weyde, who still continues so to employ it. He has also contrived an adaptation of it for general illumination in a manner which I shall presently describe.

During the past year electric lighting has been brought into extraordinary prominence by the experimental introduction of the Jablochkoff system into this country, by the development of a number of other systems of electric lighting, and by the exciting, inflated, and premature accounts of Mr. Edison's alleged discoveries, which, published primarily in a New York journal, were reproduced in the London daily press and in our provincial newspapers, with such comments and embellishments as might be thought to assist the capacity of the credulous public, and which also served the questionable purposes of those not included under the above head.

A calm consideration showed that the exaggeration of manner adopted, covered some exaggeration of fact, and that Mr. Edison's discoveries—and promised discoveries, for the disclosure of which we are still waiting — owed much of their startling character to the peculiar style of American journalism. I do not for one moment desire to reflect upon Mr. Edison's character as a scientific discoverer, he has done very much towards the development of electric telegraphy and physical science generally. I do, however, seriously doubt whether Mr. Edison has done, or will ever do, so much as his enthusiastic friends and the interviewing newspaper glossographers of the New York press have given him credit for; and although he may have made, and may still be making, great advances in electric lighting, neither I, nor anyone else, can pronounce a positive opinion upon the inventions he is credited with until we are made acquainted with their nature and details, for which we have now been waiting some months.

The most prominent of the various systems of electric lighting is undoubtedly that of the Jablochkoff, which formed a great attraction in Paris during the late Exhibition, and down to the close of the year. The Avenue de l'Opéra, and some other leading thoroughfares, were illuminated by it, as were also several public and other establishments. The Jablochkoff light is now so familiar to most of us that I need only describe it very briefly. It consists of a so-called electric candle, which is composed of two pencils of carbon connected together side by side by a strip

of kaolin, which at the same time insulates them. The light is generated by a magneto-electric machine, producing alternating currents of positive and negative electricity. This light has been applied experimentally in London to a portion of the Thames embankment, a portion of the Holborn Viaduct, and to the fish market at Billingsgate. It has also been applied in several large private trading establishments, and has also been under trial at Westgate-on-Sea. As the experiment on the Thames embankment is the largest and perhaps the most important yet tried in England, a description of the arrangements as there carried out will prove interesting, and will afford a clear idea of the system. The portion of the embankment lighted is that which lies between Westminster and Waterloo bridges, and which represents a stretch of three-quarters of a mile. The experiments were undertaken at the instance of the Metropolitan Board of Works, and the arrangements were carried out under the direction of the engineer to the Board, Sir Joseph Bazalgette, and their consulting chemist, Mr. T. W. Keates, and those gentlemen have, I believe, taken every precaution to render the trial an exhaustive one, and its results conclusive. The engine and machinery for generating the electric currents are placed in a wooden house, on the west side of the Charing Cross Railway Bridge. The conducting wires are led under the roadway to the subway, which runs under the pathway of the embankment next the parapet wall, and thence the wires are led to the lamps on that wall. The engine used is one of 20 horse-power nominal, by Messrs. Ransomes, Sims, and Head, of Ipswich, and will indicate from 60 to 70 horse-power. It is estimated that the engine is developing about 25 horse-power, and will continue to do so during the present experiment, but this estimated power will of course be verified during the trials. The apparatus for producing the light consists of a Gramme continuous-current machine, and a Gramme alternate-current machine. The latter, which is of 20-light power, is divided into four circuits, each supplying five lights, and is excited by the continuous machine. The number of electric lights on the embankment is twenty, and the farthest lamp on the eastern or Waterloo Bridge side of the engine house is 470 yards from the apparatus, whilst the farthest lamp on the western or Westminster Bridge side is 700 yards from the machinery. The total distance between these two extreme points is thus 1170 yards, and the average distance between any two lamps is 45 yards, although some of the lamps are more distantly spaced. The ordinary gas standards have been utilized for the electric lamps, which consist of holders carrying four Jablochkoff candles, the holders being surrounded by opalescent glass globes 20 inches in diameter. Each candle

is calculated to last an hour and a half, so that about six hours' supply of light is ensured without necessitating a replacement of the carbons unless anything goes wrong, which it did on one of the first nights the system was tried, when, from a defect in one lamp, the rest on that circuit were extinguished, but were relighted as soon as the defect was made good. Each lamp has a commutator for switching another candle into position just as the preceding one is consumed, and thus each lamp is kept alight for about six hours each evening. But why this important experiment is thus curtailed instead of being made complete by the lamps being kept lighted through the hours of darkness, as all the gas lamps of the metropolis and all large towns necessarily are, I cannot comprehend, unless it be for a reason which, when exposed and felt, would be fatal to the system; namely, the avoidance of the practical difficulty and expense of removing and replacing the burnt-out candles, which would in mid-winter require to be done twice in the night, involving the attendance of workmen, and the darkness consequent on the lamps in each circuit being out of use while the several lamps in that circuit were being thus refitted with candles. And this, it must be observed, is not merely a matter of expense which may be estimated, but it suggests a question as to the opportunity for committing evil deeds thus afforded to the "powers of darkness"; and it is to be feared that the criminally disposed would not be slow to seize the opportunities which would thus be periodically afforded them to exercise their professional instincts.

The main points to be ascertained in these experiments are, firstly, the difference in illuminating power between these twenty Jablochkoff lamps and the gas lights previously in use on the route, and, secondly, the cost. With regard to the first point, I may mention that the embankment is about 100 feet wide, and there were three rows of gas lamps, one row being that on the parapet wall, each lamp having two jets, the other two being those of the single jet lamps on the edge of each pathway. The total number of gas jets was 170. Now, each naked Jablochkoff light is estimated by its proprietors to be equal to 100 carcel burners, each burner being equal to ten candles. The electric lights should therefore equal 20,000 candles. Inasmuch, however, as the opalescent globe by which the light is surrounded is estimated to deprive it of 50 per cent. of its illuminating power, the light becomes at once reduced to 10,000 candles; each of the 170 gas burners was equal to eight candles, so that the total illuminating power of the gas may be taken as equal to 1360 candles; but, as the sweetness of the rose is wasted on desert air, so is the radiant effulgence of these electric lamps, placed as they are on the parapet wall, in part lost by being

wasted to the extent of another 50 per cent. on the adjacent watery highway, and this brings the total utilized illuminating power down to 5000 candles for the embankment: but, as there is a proportionate waste of light from the gas burners in the intermediate lamps on the wall, which may be stated at 320 candles, the comparative results will be as follows:—

Loss of light on river-side from the twenty electric lamps	5000	candles.
Loss of light from the intermediate gas lamps	320	„
Net loss or waste of light as compared with gas	4680	„

involving the loss of the value of the light given by about 14,000 candles in a single winter's night in lighting the roadway and footpath of that portion of the embankment between Westminster and Waterloo Bridges, that quantity being wasted on the river; a result which would not be approved and sanctioned as a permanent arrangement by the ratepayers of the metropolis, and which goes to show that the embankment is not the most economical place in London for the exhibition of electric lighting.

But, leaving this last adjustment out of the question, the electric light should, on the data given, afford about eight times the light given by the gas. There is undoubtedly a very great improvement in the lighting of the embankment, but whether it amounts to the increased power which has been claimed for it we have yet to learn from the report which will be made by the eminent engineer, and the no less eminent chemist, in whose hands the matter has been placed by the Metropolitan Board of Works; meanwhile, the public are being treated to a display of this artificial, cold, moonlight illumination in conjunction with gas. The experiment was practically commenced on the 16th of December last, and will extend over three months from that time, or longer if found to be necessary.

The experimental trial of the Jablochkoff candle at Westgate-on-Sea was undertaken at the instance and the expense of Mr. Edmund F. Davis, of St. Peter's, Thanet, and to whom a large portion of Westgate belongs. The arrangements for and the carrying out of the experiments were entrusted to Mr. W. H. Bennett, of Westminster, and Mr. W. A. Valon, of Ramsgate, both members of our Society. Six lamps were employed, placed 80 yards apart. They were similar to those on the Thames embankment; so were also the general arrangements for producing the electric current, although necessarily on a smaller scale.

Here, again, however, as on the Thames embankment, the lamps were only kept going while one set of candles lasted in each, which in this case was four hours each night, which, in my opinion, is not satisfactory, as the test of a careful nursing of this method of lighting for four hours each evening cannot be considered conclusive as to its actual cost; for it is not at all clear that, to arrive at the true result, you have only to multiply four by four to get at the difference of cost between four hours' lighting and sixteen, which is about the time required for keeping artificial lights going in a winter's night; and the disturbing elements in such a matter as this are such that, to determine finally and conclusively the question of exact cost, the practical difficulties should be encountered by actual working, and not be left to computation. The report of the two engineers engaged on these experiments, which has been published in the 'Journal of Gas Lighting,' and in a separate form, is a valuable contribution to the literature of electric lighting, showing how the results brought out were arrived at, and enabling critics to test the conclusions, which are set forth in the clearest manner; leaving nothing to be desired but the solution of the question to which I have pointed attention—namely, If the cost of lighting a given number of electric lamps in an open thoroughfare, say for five hours per night per annum, costs so much, how much will the cost per lamp be increased if the lighting be continued through each night, as is required in the usual way, making up the ordinary number of 4327 hours per annum?

An experiment so exhaustive as this could not be expected to be tried at the expense of a private individual, as were those at Westgate-on-Sea; but I cannot help thinking that if any experiment was worth being tried at all by the Metropolitan Board of Works, it should have been an exhaustive, and not a tentative one.

The relative cost, exhibited in the report by Messrs. Bennett and Valon, of electricity and gas for public lighting for a period of twenty-four days, four hours per day, equal to ninety-six hours, the quantity of light being equal in both cases, is 40*l.* 9*s.* 4*d.* for electric lamps against 16*l.* 15*s.* 4*d.* for gas, the latter being for gas of practically 14-candle illuminating power, charged at 6*s.* 6*d.* per 1000 cubic feet, but if of the quality and price charged in London, the cost would amount to only 7*l.* 18*s.* 9*d.* This brings me to the consideration of the startling discrepancy between the estimated amount of light of the Jablochkoff lamp, and the results brought out by actual measurement at Westgate-on-Sea, 500 candle-power being claimed and 197 proved. And this appears to me to open up an important question for

physicists and mathematicians as to the apparent difference between the penetrative power of the electric light and gas light. The question has occupied my mind, but at present I have failed to devise a method of determining the *quantity* of the light, and can only say I suspect that the old law of the illuminating power of light being as the square of the distance will not apply to the electric spark, and I feel that we want to determine the difference in value between a light from a flame and that from a succession of sparks. In dealing with the practical experiment on the Thames embankment, I have adopted the estimate of the *intensity* of the electric lamp as given by its advocates, and am not disposed to challenge its accuracy; but let it be borne in mind that *intensity* is one quality and *quantity* another; and as a practical man, concerned in the production of artificial light, I am of opinion that the electric light is inconveniently intense, and so deficient in volume or quantity as to be inapplicable to all the ordinary purposes for which artificial light is required, where economy is regarded.

With regard to the cost of the Jablochkoff light in England, no authentic particulars, so far as I am aware, besides those I have just referred to, are at present to hand. In France, however, especially in Paris, where it has been largely tried, the cost appears to have been ascertained in several instances. I am not able to vouch for the correctness of these figures, but have no reason to doubt their correctness, as they have been made public on the authority of M. J. Allard, the chief engineer of the lighting department of the city of Paris, and they refer to the application of the Jablochkoff system in the Avenue de l'Opéra. It appears that the municipality of Paris paid the Société Générale d'Electricité 37 francs 2 centimes per hour for the 62 lamps in use there. These 62 lamps supersede 344 gas jets, which were previously used, and which cost the authorities 7·244 francs per hour. The electric illumination, however, was considered as equal to 682 gas jets, or about double the original illumination—that is, to a cost of 14·45 francs per hour as against 37·2 francs for the electric light, the cost of which therefore is 2·6 times that of the gas. The contract for lighting by electricity was terminated by the city of Paris on the 30th of November last, and the authorities declined to renew it except at the price paid for gas, namely 7·224 francs (or about 6*s.*) per hour, and that only until the 15th of last month. Those terms were accepted by the Société, so that the price paid to them was at the rate of about 1⅛*d.* per light per hour. I am informed that the Société place their expenses at 1·06 francs, or just 11*d.* per light per hour, so that the second contract could not have proved very remunerative. I understand,

however, that as far as the public thoroughfares are concerned, electric lighting has been discontinued in Paris.

The next system of electric lighting to which I shall direct your attention is that of M. J. Rapieff, which was first brought into public notice during June, last year. M. Rapieff's object was to produce an absolutely fixed point of light in connection with the subdivision of the electric light, securing perfect continuity of illumination irrespective of the necessary renewal of the carbons or of any accidental interruption of the current. This object he has succeeded in accomplishing. The light is produced from two pairs of carbons placed one above the other, the upper pair being inclined towards each other in V form, and the lower similarly inclined, but in Λ form, the point of ignition being the junction of the two points of the V's. The carbons are carried in fixed holders, and they are kept in juxtaposition by means of a light endless cord, on which is suspended a weight, the cord passing over a small pulley attached to each holder. If anything occurs to break or interrupt the current, a small electro-magnet comes into operation, and instantly re-establishes the light. The change of carbons is effected without breaking the continuity of the light. By withdrawing the remaining portion of one nearly consumed carbon at a time, and replacing it with a new rod, no interruption ensues, as the voltaic arc is maintained between the points of the three remaining carbons. The current may be supplied by a Gramme machine, giving either continuous or alternating currents. The simplicity and distributing character of this light led to its adoption in the printing offices of the 'Times,' and for some months past that paper has been printed by this electric light. Six lamps have been found sufficient to light the large room which contains the whole of the Walter printing presses employed in producing the daily issues of that journal.

Before noticing the next development in electric lighting—which is the Lontin light—it is necessary that I should refer to the Serrin and the Siemens lamps, because the Lontin light is a modification of the former. The Serrin lamp is one of those few in which only a single light is produced, the shortening of the carbon electrodes by combustion being followed up by means of a complex train of clockwork. The light is produced from a Gramme machine giving continuous currents. The single light afforded answers the purpose of lighthouse illumination, and is suitable under other isolated or special conditions, although the apparatus possesses defects which are well known and which are quite irrespective of its inapplicability to the purposes of subdivision of the electric light. The Siemens lamp is similar in

principle to the Serrin, inasmuch as it only produces a single light, and the distance between the carbons is maintained by the aid of machinery, although of a much more simple character than that of the Serrin lamp. Should the carbons approach too closely they are separated by means of an electro-magnet which is made to act upon the mechanism of the lamp, so as to restore the voltaic arc. The current is produced by a Siemens dynamo-electric machine. This system of electric light is in extensive use for lighthouse and other similar purposes, but Dr. Siemens proposes to utilize it for street lighting by placing the lamps about 100 yards apart and at high elevations. Each lamp would be covered by a metallic reflector, so shaped as to diffuse the light over a considerable length of a street without throwing any against the fronts of the houses. But this may be regarded as "a dream and nothing more."

To return to the subject of the more recently developed systems, the next in chronological order as regards its introduction to the British public is the Lontin light, to which I have previously referred. For some months during last year passengers through the Strand had an opportunity of observing this light exhibited at the Gaiety Theatre, and I am not aware that it has been applied elsewhere in England. This light is produced by a modification of the Serrin lamp, and the current is obtained from a Lontin machine producing alternating currents. The system is limited to a productive capacity of two lights per circuit and three circuits per pair of machines; these lights are still in use outside the Gaiety Theatre. This system has been applied to the stations of two railways in Paris with satisfactory results. In 1877 a series of experiments were carried out with it at the Paris Terminus of the Paris, Lyons, and Mediterranean Railway. The passenger station was lighted, and the results proved so satisfactory that the Company entered into a permanent contract with the proprietors of the Lontin light for lighting their Paris goods station with twelve lights, at a charge of 5*d.* per light per hour. The Western of France Railway Company have had six Lontin lights in the goods station at the Paris terminus, St. Lazare, since May last year, and twelve lights in the passenger station since June. Careful experiments showed the cost there to be 8*d.* per light per hour, inclusive of interest. I am not acquainted with the conditions under which these lights are produced at the two stations, so I am unable to account for the difference in cost. It is clear, however, that it costs the Western of France Company 3*d.* per light per hour more than the Paris and Lyons Company have to pay for the same thing.

The next system for notice is the Wallace electric light,

which is the invention of Mr. W. Wallace, of Ansonia, Connecticut, and which was first shown in England in the early part of October last by Mr. Ladd, the well-known philosophical instrument maker. The lamp consists of a light metallic frame, carrying two plates of carbon, each 5 inches long by 4 inches wide, the upper or positive carbon being ½ an inch, and the lower or negative a ¼ of an inch in thickness. The carbons are held endwise one above the other, one being fixed in the lower part of the frame, and the other being free to move vertically above it guillotine fashion. On the top of the frame is a small electro-magnet, which carries on its armature an ingenious and simple clutch which grips a brass rod connected to the frame of the upper carbon. While the current is off, the carbons rest one on the edge of the other, but directly the current is switched on, each lamp in circuit adjusts itself. The magnet, becoming active, raises its armature, which, gripping the upper carbon holder, raises the carbon a sufficient distance to establish the voltaic arc. This arc or point of light travels gradually from one end of the edges of the carbons to the other until so much has been consumed that the distance between the carbons is too great for the current to bridge over. The current thus being cut for an instant, the magnet ceases to hold up the upper carbon, which falls, through gravity, and on making contact instantly resets itself. The point of light then travels back to the other end of the plates, on reaching which the operation of resetting is automatically repeated, and so on, so long as the carbons last, which is estimated at twenty hours. The light of each lamp is estimated to be about 800 candles, and the cost of the carbon in each lamp is placed at ½*d.* per hour. The machine by which the current is generated for these lamps is the Farmer-Wallace dynamo-electric machine, which produces a continuous current, and is capable of supporting a number of lights in one circuit, according to the amount of power absorbed, which is calculated at one horse per light, and about one for the line. The machine being duplex in construction, can be used as two distinct machines giving two separate circuits. It is this machine with which Mr. Edison has been carrying out his experiments in electric lighting, and it is much in favour in the United States.

The Wallace light is now under trial at the Liverpool Street Station of the Great Eastern Railway, where it has been applied to the upper ends of two of the platforms. There are three lamps on each platform, and they are placed 37 yards apart. The lamp standards are 20 feet high, and the electric lamp is contained in a plain glass lantern, of the inverted bell pattern. The current-producer is a Farmer-Wallace machine of 10-light power,

and is placed in a temporary building at the far end of the platform, and one-eighth of a mile from the farthest lamp, the circuit wire being a quarter of a mile in length. The machine is driven through countershafting from a Robey engine of 10 horse-power nominal. That portion of the station in which the electric lamps are placed is undoubtedly well lighted, but the brilliancy of the light is rather intense at first, owing to the transparent nature of the glass used. The eye, however, becomes accustomed to the light in a short time; but whether this would in time be at the expense of vision I am not prepared to say. It is a question whether a slight toning of the glass would not be an improvement. It is true the lights are 20 feet high, and therefore comparatively out of the line of near vision. But this great height reduces the illuminating power of the light as regards the platforms; and on carefully observing it, I came to the conclusion that the modification desired would be best attained by placing the lamps at a lower level, and using tinted-glass lanterns or globes. But it is very doubtful if, after all the modifications and improvements which may be practicable, such a light can be considered safe or desirable for such a station with its enormous traffic, for there is no calculating the mischief—calamity, indeed—which might ensue in the event of the sudden extinction of the lamps, a contingency to which all electric lights are peculiarly liable, as proved by experience upon the Thames embankment, the Viaduct, at Westgate-on-Sea, and elsewhere.

The Werdermann electric light was brought into notice early in November by Messrs. J. Berger Spence and Co. Unlike most other inventions in this direction, M. Werdermann does not deem it essential that a certain definite distance should exist between the carbon electrodes. He therefore discards the voltaic arc, and places his carbons in actual contact, thereby producing a steady light by incandescence. This light is produced by a rod of carbon which impinges upon the face of a disc of the same material, forming the negative of the lamp. The disc is placed at the top, and is about 2 inches in diameter and 1 inch thick, the under side being convex. The rod is about $\frac{1}{8}$ of an inch in diameter, and is held vertically under the disc in a guide or collar, and its lower end is fitted in a small cap or holder, to which the ends of a fine cord are attached. The cord is led over pulleys and down to a counterbalance weight, and so acts in keeping the upper point of the carbon rod gently pressed against the under side of the disc. By this means the consumption of the rod is uniformly followed up. A small Gramme continuous machine supplied a current to ten of these lamps in the same circuit. A conducting cable was laid on from the

machine to the row of ten lamps, and from it ten wires were led up, one to each lamp. The current passes from the lamps by a return wire to the machine. The light produced was steady, but small, and of moderate intensity. I am not aware that the Werdermann light has as yet been adopted on a practical scale.

I have already referred to the Van der Weyde electric light, which was first publicly exhibited in Regent Street at Mr. Van der Weyde's studio, amid the blaze of gas illumination on the last anniversary of the birth of H.R.H. the Prince of Wales. This light is ordinarily utilized by its inventor for photographic purposes, to which he was the first to apply it. It is not, however, the production of the current, nor the means of converting it into light, at which Mr. Van der Weyde has laboured, so much as the rendering of the light produced available as an illuminator without wasting it, so to speak, and yet without throwing the rays directly upon the object to be illuminated. This he accomplishes by using the carbon rods as electrodes placed vertically one over the other, the upper rod being $\frac{3}{8}$ of an inch, and the lower $\frac{3}{4}$ of an inch in diameter. These are placed near the mouth of a concave reflector, but none of the rays of light reach the spectator direct, as they are intercepted by a disc of opal glass about 4 inches in diameter. The whole body of the light is gathered up in the reflector, and thrown out in a flood of pure white light. The current is produced by a Siemens dynamo-electric machine giving continuous currents, and driven by a small Otto silent gas engine. So far as I am aware, the Van der Weyde light has not yet been applied to purposes of general illumination.

The most recently developed system of electric lighting is that of Mr. Henry Wilde, of Manchester, which was first exhibited towards the end of December last. This apparatus consists of an electro-magnetic induction machine producing alternating currents and a carbon-holder or lamp of simple construction. The machine is the outcome of several years of patient study and practical research, having passed through many stages since the first one of its kind was exhibited by Mr. Wilde before the Royal Society some twelve years since. It consists of a disc of cast iron, which is mounted on a horizontal driving shaft. Attached to the disc and projecting from either side of it, are ten cores or armatures, while on either side of these again are ten cylindrical electro-magnets, which are fixed to the side framing in line with the iron cores on the disc. The two circles of magnets consequently have their poles opposite each other, with the disc and its circle of iron cores revolving between them. The machine is of 10-light power, and the current from it is led away by conductors to the

lamp in the usual manner. The light is produced by means of a pair of carbon rods placed side by side in a pair of holders parallel to each other in a vertical position with a space of about $\frac{1}{8}$ of an inch between them. If this space was filled in with an insulating material, a Jablochkoff candle would be produced. But it is not, and on producing the electric light from the ends of these carbons, they burn steadily down until they are wholly consumed. By means of an electro-magnet the automatic lighting of the carbons is ensured, and the extinction of any of the lights on the circuit by the interruption of the current prevented. The experimental trial of this light fully demonstrated these points, and showed that a good light was produced, capable of being utilized for purposes of illumination. It may be that its introduction has been too recent to allow time for its practical application, at any rate I am not aware that it has been so applied.

I have now placed before you the various systems of electric lighting which have been brought prominently before the public during the past twelve months. In addition to these, there are several which have been heard of, but never seen, and which it would be waste of time to discuss. I need hardly say that the records of the Patent Office showed last year a great increase in the number of applications for patents in respect of electric lighting over previous years. During the year 1877, although a large amount of interest was evinced in electric lighting, only thirteen patents were applied for in this connection, whilst last year the number reached nearly to one hundred. From what I have said it will be seen that there are at least nine systems of electric lighting for the public to choose from, all of which are more or less applicable to purposes of general illumination. As a matter of fact, however, besides the Serrin and the Siemens systems which are in general use for lighthouse purposes, only one other has ever been tried experimentally for public lighting —I mean the Jablochkoff; whilst the Rapieff and the Wallace systems have been utilized, each in one instance only, and those for purposes more or less private, and this in the face of the alleged enormous demand for the electric light of which we heard so much a few months since. The fact is, that people are very sensibly waiting for the results of the practical trials now being made by public bodies, and to which I have referred. These results, which we may assume will be thoroughly reliable so far as they extend, will show the exact cost of electric lighting as against that of gas, and all public bodies and local authorities will then be able to see whether they can afford the great extra cost, which up to this time experience has shown attends its employment. There can be no doubt but that for special

purposes, as in the 'Times' printing-office, where a high standard of illumination is a *sine quâ non*, and where the additional expense it entails is of no moment, the electric light will find a wide field for its adoption. Vestries, however, will find it a less easy question to solve, for however much the British public may like to promenade by the light of electricity, they will object to pay for the extra illumination if it entails extra cost, and vote it to be for the present mere "moonshine," notwithstanding the fact that in popular estimation the electric light has come to be regarded in our day as the "light of the future," as no doubt in some sense it may be, but there is all the difference in the world between the proximate and the far distant future, and the apologists for an electric light have never defined this difference. Hence the British public are left to the exercise of their own imaginations as to whether the electric light future may be five or five thousand years; it would be presumption on my part to pretend to draw the line between these two periods.

But while the electric light has been shedding its rays over some of our metropolitan thoroughfares, dimming the gas lights by its effulgence, people have insensibly come to think that there is no possibility of obtaining from gas a greater amount of light than at present is generally afforded, save under very exceptional conditions, and at an extravagantly increased cost. The comparison between the electric light and that of gas proved odious on account of the comparative paucity of the light emitted by the latter in our thoroughfares. But people did not pause to consider that the low rate of illumination afforded by the public lamps was solely due to the circumstance that they are placed at great distances apart, and the consumption of gas in each is kept very low from motives of economy on the part of the representatives of the ratepayers. A fair comparison could only be made between the two systems by a liberal, but not an extravagant, use of gas; and that this neither involves exceptional conditions nor a prohibitory increase of cost, the Phœnix Gaslight Company have conclusively shown. They have done this by re-modelling the lighting arrangements in that portion of the Waterloo Bridge Road which lies between the bridge and the South-Western Railway Station, a distance of 500 yards, at their own expense, and with the consent of the Lambeth vestry. By this means the Company have been able to furnish to the lighting authorities and the public a fair standard of comparison both as regards illumination and cost. The arrangements were planned and carried out by the Company's engineer, Mr. Corbet Woodall, a member of this Society. The 500 yards run of road was previously lighted by 22 gas lamps, six of which were placed at the

intersection of the York Road with the main thoroughfare. The total light thus afforded was about equal to 264 candles, and the total cost to 5¼*d.* per hour or 93*l.* 10*s.* per annum. The 22 old lamps have been removed and replaced by 48 others of new design, each giving the light of 15 candles instead of 12 candles as previously, and the distances between the lamps being reduced to one-third of what they were previously. The lamp standards have been reduced in height by about 2 feet, and the lanterns are of a new pattern, somewhat diamond shaped in vertical section. On each of the two refuges at the York Road crossing is a single lantern carrying a burner giving a light of 130 candles in one case and of 200 candles in the other. At each of the corners of the intersecting roads is placed a lamp having an Argand burner of 50 candle-power, which, with the lights on the refuges, afford a high illuminating power at this crossing; at the end of the road next the bridge the old lamp standards have been fitted with Argand burners of 50 candle-power. The burners used are those designed and made by Mr. William Sugg, a member of this Society, whose name is a household word in connection with the improvements he has introduced in gas burners and gas lighting.

Those who have seen the road thus lighted will agree with me that there can be no question whatever as to the satisfactory nature of the improvement effected. The entire section of the roadway is excellently well lighted—unaided, too, for the greater part, by the side lights of shops—and the York Road crossing brilliantly so. This point being conceded, let me next direct your attention to the question of cost. Of course this shows an increase upon the former expense, but with the result of an immensely superior illumination. I take Mr. Woodall's figures, which are as follows:—

		£	s.	d.
Cost of lanterns, posts, burners, fixing, &c.		120	0	0
Interest on first cost at 10 per cent.		12	0	0
Cost of lighting, cleaning, repairing, &c., at 15*s.* per lamp per annum—the price paid to the Company		40	10	0
GAS—				
48 burners at 6 feet per hour	288 feet			
8 „ 15 „	120 „			
2 „ 35 „	70 „			
Total	478 „			
per hour, which, multiplied by 4200, the number of hours during which lamps in this district are alight in the year, gives 2,007,600 cubic feet of gas at 3*s.* 4*d.* per 1000		334	12	0
Total per annum		£387	2	0

It will thus be seen that the cost of gas used in thoroughly lighting 500 yards of a broad road amounts to 1*s.* 7*d.*, and the total cost, including maintenance, to 1*s.* 10*d.* per hour. It is, however, proposed to reduce the amount of light after midnight, which would bring the cost to 1*s.* 2*d.* and 1*s.* 5*d.* respectively. It is not proposed to give this increase of light generally and indiscriminately; to do so would be to raise the lighting rate of a district to an objectionable and unnecessary extent. In the case of the 500 yards of roadway under notice, the cost would be raised from $5\frac{1}{4}$*d.* to 1*s.* 5*d.* per hour. It is only in the more public roads and at dangerous intersections where such brilliant illumination is desirable, and where it is proposed to effect an improvement. Taking the electric lighting on the Thames embankment and the Holborn Viaduct into comparison, I would observe that on the latter the lights are about 60 yards apart, which is too great, and produces dark spaces between them. Taking 50 yards as the proper distance apart, and which is about that of the lamps on the Thames embankment, it is estimated that it would require twenty electric lights to do the work which is done by the gas in the Waterloo Road. The carbons alone for these twenty lights cost, I am informed, 5*d.* per hour per lamp, and this one item would therefore amount to 1750*l.* per annum. Taking, however, the cost of the Jablochkoff light at 1*s.* per hour per lamp as a fair price—and that is the price paid by the municipality of Paris for the first trials—the cost would be 4200*l.* per annum, as against 387*l.* for gas. These figures make it quite clear, so far, that in the matter of cost electric lighting —at any rate, the Jablochkoff system—cannot at present compete with our old friend gas. The Waterloo Road experiments prove that if superior lighting is needed it can easily be had to any extent, provided the public are willing to pay for it. They also prove that by a judicious arrangement this superior lighting can be obtained without incurring a prohibitory cost; and I cannot help adding that, for a very unimportant addition to the present cost, a considerable improvement may be effected in the public lighting of the metropolis.

I have occupied your attention thus largely with the question of the electric light partly from necessity and partly from choice. From necessity, because it has formed the leading—almost the only—subject of scientific interest and development during the past year; and from choice, because I desire to place on record in our Transactions such practical facts as are obtainable on this interesting subject. These may possibly prove of service and to the convenience of future investigators in this direction, both as a guide and a warning. There is reason for believing that the science of electric lighting is far from fully

developed, and that it has an important sphere of usefulness before it. But I believe that usefulness will not be so universal, nor its future so immediate, as its sanguine advocates think; nor, on the other hand, am I of opinion that its usefulness will be so very limited, and its future so utterly remote, as some of its opponents hope. It will find its present uses, as I have already said, where expense is a secondary consideration, and will almost certainly lead to a more liberal use of the well-established and less costly means of illumination by gas, which, in my opinion, will always hold its own. It is a singular fact, and one which has been commented upon lately by physicists, that this electric light outburst is coincident with the period of solar spots, through which we are now passing, and that it has been so before. Touching these sun-spots, I may observe that they are supposed to be rents in the solar photosphere, caused by a violent uprush of solar gas. It is also assumed that the darkness of these spots is occasioned by the inrush of the corresponding counter-current from the colder solar atmosphere, and the consequent decrease of radiation on that side of the rupture. These periods of sun-spots occur every ten years, and it is a very remarkable circumstance that the electric light panic occurs coincidently with those periods. It is further stated by those who are close observers of these signs of the times that the period of maximum excitement corresponds precisely with the years of minimum spots. I do not attempt to explain this curious concatenation of circumstances, but there is at least one thought which forcibly suggests itself to my mind in endeavouring to reconcile these facts, and that is, that besides solar, there may also, in the recent period of temporary depression in the value of gas property, have been *lunar* influences at work in our midst during the year.

In conclusion, Gentlemen, permit me to thank you for the patient hearing you have given me for a second time, and to wish you individually as members of our common profession, and collectively as members of the Society of Engineers, that measure of success in the year before us which, if it does fall a little short of your expectations, may at least be fully equal to your requirements. More than this it would be perhaps unwise in any of us to hope for until the balance of those contending forces which are now so actively at work amongst and around us shall have been happily restored.

March 3rd, 1879.

ROBERT PAULSON SPICE, President, in the Chair.

THE NEW PITS AND HAULING MACHINERY FOR THE SAN DOMINGOS MINES IN PORTUGAL.

By Joseph Bernays, Vice-President.

The San Domingos iron pyrites mines in Portugal form one of a group of three, from which the principal supply of ore is obtained which is sent from the southern Spanish peninsula to this country. These mines are in close contiguity to the small streamlet "Chanza," about 12 miles above its embouchure with the Guadiana river, which it joins at a place called Pomarão, about 50 miles from the sea. The other two mines, forming the same group, and competing with each other, are the "Rio Tinto" and the "Tharsis" mines, both situated over the border, in Spain.

About twenty years ago the San Domingos mines were in the hands of a Spanish exploring company, who had no real intention of working them. They had confined themselves to clearing out the old Roman adit and a few of the old Roman shafts, and had broken a few hundred tons of ore. There was no road whatever between the site of the mines and any possible shipping port on the Guadiana river, 12 miles distant, Pomarão itself being only the name of a locality without either buildings or inhabitants. The buildings at the mine at that time consisted of a rough house, formed out of an old hermitage by the addition of a small carpenter's shop and smithy for sharpening miners' tools, and some mud and stone huts, built for themselves out of the materials at hand by the few miners and workpeople employed.

The scene, however, soon changed under the energetic and spirited management of Mr. James Mason, of Eynsham Hall, Oxon, who at that time became the proprietor of the mines, ably assisted in London by his representative and relative Mr.

Francis Tress Barry, of Clewer, who has since joined Mr. Mason in one firm. After having carefully studied the country and the river, Mr. Mason fixed upon Pomarão as the shipping port, where proper loading stages were erected, and where vessels and steamers of considerable tonnage can lie safely at anchor. The right of way was next acquired for a road from the mines to the port, and a road was constructed for mules and horses, which formed the first means of communication. Then came the widening and improving of the road suitable for mule carts for the carriage of the first ore for shipment, and also for bringing up building materials to the mine. Subsequently new ground was taken in to allow of easier gradients and curves, and a railroad was laid down of 3 feet 6 inches gauge, which was first worked by mules, but finally taken possession of by the iron horse some time in 1861. The work at the mines themselves was, however, during that interval proceeding rapidly. The mass of ore, which originally was reached by means of shallow levels and galleries, was now relieved of its superincumbent weight of earth and stones, and laid entirely bare to a large extent for open workings, the shallow levels and galleries were extended in all directions, new and deeper levels were attacked, hauling and pumping engines and boilers, with the necessary repairing shops, were erected, and the whole assumed the appearance and importance of a large and valuable industry. In busy times more than 2000 people are now employed in various parts of the works; there are neat streets of cottages for the miners, rows of good houses, with gardens, for the managers and employés, a central office, chapel, schools, &c., and the whole is carried on in a systematic and comprehensive manner under the liberal direction of Messrs. Mason and Barry, assisted by able and competent resident managers and heads of departments.

In 1872, when the author first became acquainted with the mines, the ore was raised to the surface of the ground through three tunnels, one of which, leading to the upper levels, was worked by locomotives direct, the others by means of fixed hauling engines and wire ropes. As the trade increased, and the quality of the ore became better known, however, it was found that it would be desirable to attack a still lower level of the ore, and to have a separate outlet for the same with connections, if necessary, to the other levels. The question then arose, and was discussed at some length, as to the best method for accomplishing that object. Various methods were submitted. One plan suggested, was to drive another tunnel, with

a gradient similar to the steeper one now in use, viz. on an incline of 3 or 4 to 1. The tunnel to commence near the mouths of the existing tunnels, and to be worked by means of fixed hauling machinery erected in the vicinity of the present engines, the rails to be laid in such a way as to allow the empty descending trucks to partly counterbalance those which were brought to the surface filled. Another plan proposed was to drive a tunnel of less inclination and greater length outside of the principal mass of ore, and parallel to its main direction, touching the ore at the lowest practicable level by means of a curve, and brought in contact with the higher levels by means of special curved galleries. This tunnel could have been driven at a gradient of 1 in 20 or thereabouts, and could thus have been easily worked by our ordinary locomotives, which are employed on a line the heaviest incline on which is at the rate of 1 in 19.

The next plan, that recommended by the author, was to sink vertical shafts outside of the principal mass down to the deepest level, with suitable landings at any of the higher levels with which it might be desirable to connect the system. Cages and winding engines to be used similar to the plan generally adopted, the ascending and descending cages balancing each other. Yet another plan was examined, viz. the use of inclined shafts or pits, with cages on which the trucks would be placed and pulled up by means of winding engines, the empties balancing the full trucks, as in the previous plan. Each of these propositions having been carefully discussed between the proprietors, the resident officers, and the author as the consulting engineer, and an estimate of the probable cost of each arrangement having been made, with due consideration of the local difficulties in each case, the author's scheme of the vertical pits was finally approved of and adopted, and is now in course of execution.

The next point to be settled was the size and shape of these shafts, and here several features had to be taken into consideration. First, as to the size. It has been the custom at the mine, since a railway was first laid down, to have all the lines, both above and below ground, of the same gauge, and all working trucks of approximately the same size, in order to avoid waste and loss in loading and unloading the ore. Thus any truck loaded at any part or level of the mine can by one or other of the appliances already mentioned be taken to the surface and despatched on the railway journey down to the shipping place without the expenditure of any further labour.

The writer need not dwell upon the particular advantages of that arrangement, as the saving in time, labour, expense, and wear and tear wherever such a system can be carried through will be evident to everyone. When, therefore, the question arose as to what gauge of rails and what size of trucks to employ in the new levels, it was speedily agreed to adhere to the gauges and sizes in vogue, although the new and lower levels would for many years to come be carried on quite independently of the rest. The gauge of rails is 3 feet 6 inches. The trucks in use carry each about 4½ tons of ore. Their bodies are of iron, about 6 feet long × 4 feet wide × 2 feet deep, with one end made to open for the discharge of the ore. The underframes are of oak, carried on four wheels, each 2 feet diameter on tread and fitted with steel tyres. There are no bearing springs nor spring buffers, the axle-boxes are simply bolted underneath the frames, with a thick piece of vulcanized indiarubber between, and the drawbars take hold of the underframes through the same medium. The total length over the ends of the sole-plates, which form dummy buffers, is 8 feet. There are at the mine also a few varieties of side-tipping trucks, holding 5, 7, and 10 tons each respectively, but as these are not used underground, and are required only for special local purposes, they need not at present be further considered. On a future occasion the author may be able to describe a new tipping arrangement which he has applied to some of the heavier of those side-tipping trucks, and which appears to work satisfactorily.

The size of the trucks being given as just described, determined of course the size of the cages for raising the same, and this settled the size of the shafts. Next the question of their shape had to be considered. The experience of the mine having been principally gained from tunnelling and shallow pits, and these having always been made secure by heavy timbering, it will appear natural that a shaft should have been demanded in the first instance of rectangular section, of such size as to admit of the two cages side by side with a timber partition between them, and the whole heavily timbered. But after very considerable discussion and counting of the cost, accidentally aided by a rather heavy conflagration in one of the timbered tunnels, the author's plan of two separate round shafts, lined with brick or stonework where required, was at length accepted as the final arrangement. These shafts are 11 feet diameter in the clear, each providing space for one cage only, and are intended to reach a depth of about 130 yards.

Yet another point of interest remains to be brought under notice, before proceeding to explain the drawings and the arrangement of the machinery, as determining the power and size of the entire lifting apparatus. It has been stated that the load of ore carried by each truck is about 4½ tons. Add to this the weight of the truck itself of 2 tons, and that of the cage 3½ tons, there results a gross load of 10 tons. Allowing further 1 ton for the weight of the rope when the cage is down and another 1 ton for friction, we get the entire load on the rope as 12 tons, which is considerably in excess of any load raised from deep shafts by means of ropes either in this country or abroad. Under these circumstances it was necessary to somewhat modify the arrangement of the machinery from that in general use at the present moment at most modern shafts, as will be seen from the drawings which the author will now proceed to describe.

Diagrams Figs. 1 and 2 represent respectively the sectional elevation and plan of the general arrangement of shafts and winding machinery. A A are the two shafts, B the overhead pulleys, C the winding drums, D the winding engines and intermediate gearing for driving the drums, E the boilers, F the chimney shaft. As it is the intention to use rock-drills fed with compressed air, in sinking part of the shafts and in driving the galleries hereafter, space has been left for the necessary machinery. The general plan shows room for air-compressors, also an air-receiver or large air-vessel G, which has already been placed in position. There is also a small smithy and workshop and store-room attached, in order to avoid the necessity of sending for small matters down to the principal shops and stores, which are about half a mile distant.

Figs. 3, 4, 5, 6, 7, and 8 give some particulars of the construction of the pits in accordance with the writer's specification. As already stated, the pits or shafts are 11 feet diameter inside in the clear. They are placed at a distance from each other of 20 feet centres, which figure also represents the difference of their respective distances from the winding drums. One of the shafts is placed 2 feet behind the other in plan (Fig. 5) in a direction at right angles to the other dimension. This gives the space required for clearance of the two flat ropes and connections, and allows of a straight lead being given to each rope from the drum to the overhead pulley. The shafts are each built of 14-inch brickwork in mortar, except at their mouths and at each opening for a gallery, where they are 18 inches thick. For 12 feet down from the top they are laid in cement,

and brick rings 3 bricks high laid in cement are introduced throughout at distances of not over 10 feet, in order to give stiffness and to retain a rigid shape. The mouths of the two tunnels are surrounded by a deep and solid layer of concrete, partly in order to prevent any surface moisture from getting near the shafts, and principally for the purpose of forming a rigid bed against any yielding of the surrounding ground, besides making a solid basis for the heapsteads.

Figs. 6, 7, and 8 represent three different stages of the sinking process, to an enlarged scale, the first showing the upper cemented cylinder nearly completed, and the second showing that cylinder finished with part of the concrete bed and the commencement of the next lower part of the steining. Fig. 8 shows the sinking proceeded with down to the springing of the arch for the tunnel or gallery, and also indicates one mode of timbering and underpinning, in ground which would not stand by itself, as in Fig. 7. It will here be right to mention that the drawings and specification for the construction of these shafts were prepared on the strength of reports from the mine, as to the nature of the ground through which the shafts had to be driven. It was reported that the ground was composed principally of metamorphic rock in small irregular pieces liable to fall in, especially if found in conjunction with water, and therefore requiring the shafts to be well and carefully steined throughout. Luckily, however, the ground was found in reality much harder and more favourable for the purpose than was at first anticipated, and hardly any steining has been found necessary for some distance down, except at the top. Indeed in some parts the material is so hard and sound, that it was not found necessary to adhere to the original round section of the shafts in such places, but to make them rectangular instead, and of such size only as will suffice for the passage of the cages.

Fig. 5 shows a sectional plan of one of the methods of joining a tunnel or gallery with each of the two shafts. The gallery is of sufficient width to allow for two lines of rail of 3 feet 6 inches gauge, one for full and one for empty trucks, whereas each branch is only for one line, points and crossings being provided to allow of the trucks being taken to or from either shaft. The trucks are pushed or pulled along the galleries by mules, and the rails are therefore provided with fixed points only, the same as on ordinary tramroads. At regular intervals throughout the shafts cross beams of wood are inserted (Figs. 3, 4, and 5) fitted to receive the upright

steel guide rails, along which the cages glide up and down, on cast-iron shoes. The catches for holding the cages in position during the time of placing and removing the trucks, are fixed on iron girders, and will be described together with the cages.

One point remains to be mentioned in connection with the shafts, viz. that the loaded trucks are not brought up to the surface of the ground, but pass through a tunnel at the brace some 35 to 40 feet below it. This gives sufficient headway for the cages, and saves the outlay for a very high pithead or heapstead. The head is built of timber, and made only of such height as to keep the overhead pulleys a safe distance from the ground. The cages used in these shafts are constructed entirely of iron, with only a wooden flooring and ceiling, and made suitable for the ordinary mine trucks. These trucks, as already stated, are 8 feet long over the dummy buffers, and many of them carry a plain lever brake, the lever standing up high above the body. The dimensions decided upon for the cages in order to suit these trucks are as follows, viz.: length of platform, 8 feet 6 inches; clear width between uprights, 5 feet 8 inches; and clear height above top of rails, 8 feet 4 inches. The cages having to carry a heavy load all in one truck, and not easily kept perfectly central, required to be constructed of great strength and stiffness with as little weight as possible, and their construction is shown in Figs. 9, 10, and 11. The two steel rails of 3 feet 6 inches gauge on which the truck runs are placed directly over two braced angle iron girders, connected in their turn to two cross girders about 4 feet apart. These by means of triangular plates are riveted to the four main upright angle irons, each of $4\frac{1}{2}$ inch $\times$ 4 inch $\times$ $\frac{5}{8}$ inch section, the whole well and securely braced by diagonals applied in every direction. The upper ends of the upright angle irons are forged into heavy eyes for holding the shackles of the chain slings which connect the cage with the lifting rope. Four channel-iron struts with suitable corner forgings and braces, constitute the upper frame of the cage, and each is further provided with four upright timbers carrying each two cast-iron shoes which run in the steel guide rails previously mentioned as fixed in the shafts.

The arrangement of catches for sustaining the cage at rest at any of the levels, is shown in side view in Fig. 12. A pair of riveted iron girders on each side of the shaft carry cast-iron brackets, in which an iron weigh-shaft can turn freely. To each of these shafts are keyed two inclined iron levers, so arranged

that the ascending cage pushes them out of the way, and when the cage has passed, they are brought back to their original position by means of short levers fixed to the outer ends of the weigh-shafts, acted upon by a counterweight and rods as indicated in the drawing. The catches are prevented from closing up too far by lugs forged on at the top, which take hold of the iron girders fixed above them, and thus ensure their proper position. The same girders also act as supports for the outer ends of the rails leading on to the cage. One of the counterweighting levers is lengthened, to form a handle for drawing the catches out of the way when the cage is to descend. A set of the catches as described is fixed in the vertical shafts on a level with each gallery from which ore is to be raised. When any lower gallery is to be served, it is necessary that the cages should safely pass all the catches on any of the higher galleries, both in ascending and descending, for which purpose the hand lever previously mentioned can be safely locked in the "clear" position, leaving the shaft quite free between the top brace and that gallery which may be in use.

The hauling engines and machinery supplied for this purpose are represented by drawings, Fig. 13, general elevation, and Fig. 14, general plan. The power is derived from a pair of horizontal coupled engines with 24-inch cylinders by 4 feet 6 inches stroke, each fitted with four Cornish double-beat steam valves, worked with the usual weigh-shafts and link motion for reversing. The engine shaft carries a light fly-wheel weighing only about 7 tons, the object being merely to protect the teeth of the wheel-gearing against damage from letting on steam too suddenly. The cylinders are steam-jacketed, as are also the covers, and the piston rods pass through glands at both ends. They are of steel, and of sufficient strength to carry the piston body free in the cylinder, care having been taken to turn the piston bodies smaller than the bore of the cylinders so that the packing rings only shall touch during the work. Motion is transmitted to the drum shaft by means of spur gear and an intermediate shaft, reducing the speed in the proportion of 5·43 revolutions of the engine to one revolution of the drum. The spur wheel on the drum shaft has 152 teeth 15 inches broad, and of 4 inches pitch, the pinion on the engine shaft has 28 teeth, and the intermediate wheel 108 teeth. The drums are of cast iron, 11 feet diameter on their working face, and each is fitted with eight double arms of timber, reaching to a diameter of 16 feet, and leaving space between them for a flat rope about 6 inches wide.

The most notable peculiarity in the arrangement of this hauling machinery, besides the return to spur gearing, will probably be found in the construction of the drums themselves. These had to be arranged with a view to allowing for the easy and quick change of working lengths of the ropes, for the purpose of raising ore from several galleries, a change which might have to be made several times in a day. Each separate level containing only a few working galleries, they are not sufficient for supplying a proper number of filled trucks to keep the engines fairly at work the whole day. But by allowing the loaded waggons to slightly accumulate in each level during part of the time, the engines can raise alternately from whichever level the output is greatest, and thus keep all properly going. If for instance the men are at work in three levels, say at 70 yards, 100 yards, and 120 yards from the brace, and they start first by hauling up all the loaded waggons from the 70 yards level, this will give the men at the 100 yards and 120 yards time to push their loaded waggons up to the shaft, and whilst these are being raised in rotation, the men at the 70 yards fill their trucks in readiness for the next day's hauling. Thus with one set of hoisting apparatus the whole of the levels connected with the shafts can be properly served, thereby saving the cost of a second and perhaps a third set of hauling machinery and shafts.

Figs. 15 and 16 represent parts of the drums showing the arrangements made to meet the requirements just described. The drum shaft is 15 inches diameter all over except in the bearings, and one of the drums is keyed to it with two sunk steel keys. The other drum runs loosely on the shaft, being held in position by collars at both sides. One side of its centre boss is enlarged to a diameter of 4 feet 6 inches, and carries twelve $3\frac{1}{2}$-inch bored holes in a circle, equidistant from each other. These twelve holes engage with twelve steel pins carried in a heavy casting, concentric with the shaft on which it forms a sliding clutch, held in position by four steel feathers. It carries a turned groove at its smaller end in which works a brass ring with two strong projecting pins, taken hold of by a hand lever, with which the clutch can be put in and out of gear. When out of gear, the drum runs loose on the shaft; when in gear it revolves with the same, and in this position the clutch is held secure and is prevented from accidentally losing its hold by two hinged iron clamps, which are thrown over it and screwed down tight with set screws. Each of the drums has a separate brake, the levers of which are connected to one

weigh-shaft, and when at work are handled by the engine-driver by means of levers jointed to one rod and handle, brought up to his position near the link reversing gear. But for the purpose of changing the length of the rope from one level to serve for another, the two brakes can be disconnected by the withdrawal of a pin, and each worked separately.

The *modus operandi* for changing from one level to another is as follows:—Let it be supposed that work has just been finished at the 70 yards level, and it is desired to start hauling from the 100 yards. The cage, which is suspended from the fixed drum, will be placed and held upon the catches at the upper brace of the shaft; the other cage, which is suspended from the loose drum, will then be down at the 70 yards level, the catches on which landing are pulled out of the way and locked in the "clear" position. The attendants now separate the two brakes from each other, tightening up each independently. They then unfasten and throw back the two iron clamps which secure the clutch to the loose drum, and draw the clutch out of gear. They then gradually slacken the brake on the loose drum, and the cage suspended therefrom will descend slowly until it reaches the catches on the landing of the 100 yards level, where its motion is arrested. The clutch is then pushed into gear and the twelve pins quickly find a bearing, thus adjusting the position of the cage to within the twelfth part of the circumference of the drum, the utmost difference being within $1\frac{1}{2}$ feet of the required length. After securing the clutch by means of the two clamps, and re-connecting the two brakes for working simultaneously, the engines are ready for hauling from the new level; and the whole operation of adjusting to that level need not take more than ten minutes to accomplish.

To return to a shallower level the reverse action takes place, the cage resting on the top catches being that suspended from the loose drum, whereas the bottom cage is raised to the next required level by allowing the engines to move round gently with the fixed drum, until the cage has risen the proper height.

The steel wire ropes for these engines will be made flat, $5\frac{1}{2}$ inches wide and $\frac{3}{4}$ inch thick, composed of seven $\frac{3}{4}$-inch round ropes worked up together, of ample strength for a working load of 12 tons, including friction and its own weight, and capable of sustaining a breaking strain of over 100 tons. They are intended to be constructed of best selected crucible cast-steel wire, carefully annealed, with wire-cores to the strands and

hemp-cores to the ropes. The best method of testing them during and after manufacture has not been finally determined upon, but it is proposed to strain to destruction a short part of each rope as it is being manufactured, then to cut off the part so tested and carefully splice new wires for the continuation of the manufacture of the ropes. The new splices would of course have to break joint properly, and on completion the whole rope could be tested in successive lengths to, say, double the working strain.

Owing to the slight speed which will be given to the ascending and descending cages, it has not been considered necessary to provide for any safety-hook or other appliance against overwinding, the connection between the rope and the cage being made with plain shackles and pins. Nor are the cages provided with any self-stopping arrangement against breakage of the ropes, as these will have a large margin of working strength and will be under daily careful inspection, while no persons will be permitted to make use of the cages when they are otherwise loaded.

The overhead pulleys are 12 feet diameter on tread, 7 inches wide, and with a guide flange each side 6 inches deep, strengthened on the outer edge by a strong bead all round, and they are cast in halves. The rims are each carried by thirty $1\frac{3}{4}$-inch wrought-iron round arms cast into the centre boss at one end and into the rim at the other, the inner ends being stepped into the boss right and left alternately, forming two complete cones of arms for the rigid support of the rim. The pulleys are keyed on wrought-iron shafts 9 inches diameter, supported on bushed bearings 6 feet apart, which are inclined at an angle to meet the resultant of the strains. Intermediate guide pulleys are also provided, each 4 feet in diameter and 12 inches wide on the rim, with deep flanges, for the purpose of carrying the inclined parts of the ropes between the engine-house and the heapstead.

The general plan (Fig. 2) shows three boilers, and space for an additional one should such become necessary hereafter. Two of the boilers as shown are expected to be quite sufficient for the work. They are of the usual Lancashire type, and kept within reasonable limits as to diameter, for convenience of shipment; but as the whole of the transport at both ends is in the present case carried on by railways, there was no need for the adoption of any particularly condensed and more complicated construction. The boilers are each 30 feet long and 6 feet diameter, with two flues of 2 feet 2 inches diameter each,

all connections are flanged from the plates throughout, no angle iron being allowed in construction for such purpose; they have the usual fittings and mountings, both the water and the coal being of good average quality. All the plates are of B. B. Staffordshire quality, except over the fire, where Yorkshire plates are used; the flues are stayed with T rings, and the longitudinal seams of the shell are double riveted. It is perhaps hardly necessary to go further into the details of these boilers, except possibly as regards the construction of the longitudinal seams of the shell, which differ from the usual construction in that they were specified to be arranged in such manner "that no two longitudinal joints of plates shall occur at the same level." In boilers as usually made the succeeding rings of plates break joint, so that those of the first, third, and fifth rings coincide, and also those of the second, fourth, and sixth, &c., with each other. In boilers made to the author's specifications each ring of plates is shifted round by a few rivets against the preceding one, so that, for instance, the horizontal seams of the third ring are about 4 inches in advance of the first in the direction of the circumference, and those of the fifth ring show an equal advance against those of the third. Any horizontal section of the boiler will thus expose only one short length of riveted joint to the bursting pressure, the remainder being solid plate, which it is maintained adds to the strength of the boiler without additional cost. The author has for some years been in the habit of constructing his boilers in that way, and the result has been quite satisfactory.

The setting of the boilers is that usually adopted, without midfeathers. The hot gases from the two internal flues travel into side flues right and left towards the front of the boiler, where they dip into one common flue underneath, on their way to the chimney. All the parts of the setting touched by the hot gases are lined with fire-brick except the return flue, and ample provision is made for cleaning.

In conclusion, the writer has only to add that since he commenced to write this paper all the machinery and apparatus herein described have been made and delivered at the mine, the sinking of the shafts has been commenced, and has not hitherto shown any particular difficulty. Water has only lately begun to get into them more freely, and arrangements will have to be made for keeping them dry. The foundations for the engines and boilers are also well forward, and should the demand for ore require it, all could be in working order in a short time. Unfortunately the present state of the ore market

is such that for the moment our ordinary means even for producing the ore are not fully employed, and that new workings will probably not be required for some time to come. The work on them has therefore recently had to be stopped, and no early date is fixed for its completion. When the new shafts are completed, and shall have been in work for some time, the author hopes to be able to lay before the Society some data as to the working of the whole of the machinery, and as to the amount of ore that can be raised with it in a given time.

The boilers were executed by Messrs. Fernihaugh and Sons, of Dukinfield (similar boilers having been previously supplied by Messrs. Galloway and Sons, of Manchester); the engines and hauling gear by Messrs. Robert Daglish and Co., of St. Helens, Lancashire; the cages and catches by Messrs. J. and G. Joicey, of Newcastle-on-Tyne.

DISCUSSION.

Mr. Vaughan Pendred said the present was the first instance he had heard of in which gearing had been used for the purpose of winding on a large scale. He had with him a letter which referred to some other winding machinery which he thought was not without interest. The paper which had just been read described winding machinery of the most modern type. That which was referred to in the letter was perhaps as old as any machinery in existence in Great Britain for winding purposes, having been put up in 1810. The most remarkable feature of the old machinery was that Newcomen's system was used for winding; that was to say, there was a rotary engine with injection in the cylinder. He did not know that there was any other instance in which injection had been used in the cylinder of a rotary engine. The following were the particulars of the engines referred to at the Farme Colliery, Rutherglen, and which had been communicated to him by the manager:—

"One of the engines, the first erected there in 1810, is 32-inch cylinder with 5 feet 8 inch stroke. It has gone almost constantly since, and has cost remarkably little for repairs. It is winding coals, one rope from a depth of 30 fathoms, and the other from 44 fathoms. It also, until recently, pumped water from a depth of 23 fathoms by an 8-inch bucket. When doing that, it drew from 150 tons to 200 tons per day, and pumped for four or five hours per twenty-four, on a consumption of

34 cwt. of dross per twenty-four hours. The next erected, one in 1820, was a 42-inch cylinder with 6 feet stroke, and it also has been at work constantly since, winding coals. Some time about 1840 it got too light for its work, and a larger cylinder, the present one, 42 inches, was put in. When that was done, a counterbalance had to be put on the connecting rod, and additional segments put on the rim of the fly-wheel. The spokes of the fly-wheel of both these engines are of wood. This engine at that time required the steam of three boilers, one of which was a waggon boiler about 22 feet long, and two egg-ended cylindrical ones about 30 feet × 5 feet. The original boilers, however, were haystack or balloon ones. The next erected, also in 1820, was to pump water, and is a 60-inch cylinder and 7 feet stroke, with cast-iron overhead beam. It works three sets of pumps, the top one being 20 fathoms deep, with a 15½-inch bucket; the second being 30 fathoms, with a 12-inch bucket; and the third set being 20 fathoms, with a 10-inch bucket, or 70 fathoms in all. This was driven by two very large balloon boilers, one of 25 feet and the other 30 feet internal diameter, the pressure of steam being about 2½ inches to 3 lbs. I should have stated that the pressure of steam of the winding engines was about the same. There is no authentic record of the consumption of fuel of these engines before certain alterations to be noticed. In 1857 it was necessary to sink the pit deeper, and a new pumping engine was erected, a 24-inch high-pressure beam-geared engine, working also three sets of pumps, one of 15-inch bucket and 20 fathoms deep, one of 12-inch bucket 30 fathoms, and one of 10-inch bucket 30 fathoms, or 80 fathoms in all; and to drive it, three egg-ended boilers 30 feet × 5 were also erected. After I took charge here, I turned the exhaust steam of this engine into one of the boilers, allowing it to blow off at 5 lbs., and worked the above 60-inch cylinder pumping engine and the 42-inch winding one by the exhaust steam, having a reducing valve to allow them to have any deficiency of steam supplied direct from the boiler. The effect of this was that we had to put up an additional high-pressure boiler, but were able to throw off the two large balloon boilers and the three required to drive the winding engine, each of which required as much fuel as the high-pressure boiler erected. This also greatly increased the power of the winding engine, and we were able to throw off the heavy weight added to the connecting rods when the cylinder had been enlarged, as also the segments on the fly-wheel; and while previously we were barely able to draw 200

tons from 80 fathoms in ten hours, we have frequently since drawn 300. Our growth of water is about 550 gallons per minute, and that and the output is drawn by a daily consumption of about 12 tons of very inferior dross, in fact the rubbish we cannot otherwise dispose of. The 60-inch engine has the ordinary parallel motion rods for keeping the piston rod perpendicular. The winding engine ones are different, and which, although they do not keep the rod perfectly plumb, do so sufficiently, considering the cylinders are open-topped. The pistons are packed by a packing of old hemp ropes opened out (untwisted) and previously steeped in hot water, and a small run of water is kept pouring on the piston top sufficiently to keep it covered. The connecting rods are very heavy, being supposed to equalize the difference between the steam pressure, about 5 lbs. now, and the vacuum. We never had a vacuum gauge on, but I believe the vacuum to be very good. The injection is direct into the cylinder, the injection pipe being contracted into a nozzle. In the earliest erected engine a movable plug is put into the nozzle, and this can be worked by a handle to allow the engineman to regulate the supply of water. After using the exhaust steam of the high-pressure engine, we had to take out the old steam inlet valves, which were the old potlid kind, and put in Cornish double beat valves, since which the engines have worked much better. We have frequently worked the 60-inch engine at eight strokes per minute or 112 feet of piston speed. The winding engine draws a cage up in sixteen revolutions in 35 seconds, or 192 feet of piston travel in the same time."

Mr. Charles Horsley said he could give an older instance of an open-top cylinder rotary engine than that to which Mr. Pendred had referred. His first practice was with an engine of that kind. It was used for pumping water from a shaft 250 yards deep, and it also raised coals. Very indifferent fuel could be used for it. The steam pressure was about 4 lbs. It was exactly such an engine as Mr. Pendred had described. In the old engine they could turn on the injection, the hand gear being simple. It could be driven almost at any speed, and the connecting rods were made very heavy to overcome the weight on the other side. He could not give any data, but he believed that it worked as economically as some of the best engines they had, and they had some of the best engines for winding coal, but still they did not supersede the old engine, and he did not see any reason why it should be superseded. It would use slack which could not be otherwise used. He believed that

there were four or five such engines working now, and they were working over sixty years ago, and therefore they dated further back than the engine Mr. Pendred had described.

Referring to the machinery which had been described by Mr. Bernays, he (Mr. Horsley) would observe, with regard to the wire ropes, that he would have had the pulleys 8 feet larger in diameter, for in cases in which wire ropes worked regularly over a pulley of very small diameter the pulling in and out and stretching of the wire ropes caused a greater wear of the ropes than would otherwise take place. It was the practice in Derbyshire for ordinary lifting to have 14-feet or 16-feet pulleys merely to raise about a ton. It was very uncommon to put on more weight than a ton at a time. The ropes travelled very quickly, at the rate of about 250 yards in about half a minute, and 14-feet pulleys had been found to be a great improvement on 10-feet pulleys; he thought that when the machinery at the San Domingos pit had been worked for some time it would be found that pulleys of a greater diameter were necessary. He should like to know why there was intermediate shafting. That would give extra friction and wear and tear of the intermediate shaft bearings and wheel, and he thought it should have been avoided. As to the weight lifted, he questioned whether it would not be more expedient, instead of lifting 4 or 5 tons at a time, to raise only about one-half or one-fourth of that weight, and work the drums much faster. In some of the collieries of the ironworks with which he was connected they brought up 1000 tons a day very easily, and yet raised only about 1 ton at a time. The cheapest plan was found to be to work quickly and not bring up too much weight. The engine used would be about 50 horse-power. One of the open-topped cylinders worked 250 yards and brought up 300 or 400 tons a day. He thought that it would be expedient to have a safety stop at the top of the pulley, because whether they worked slowly or quickly the engineman would sometimes bring them over the head gear. It appeared that the shafts had been designed for bad ground, but however bad the ground he questioned if 18 inches of brickwork be required even to a 14-feet shaft. He thought some arrangement should have been made for pumping. He did not know whether water came into the pit.

Mr. Bernays: Very little.

Mr. Horsley said that let the water be ever so little it would have to be taken out.

Mr. V. Pendred observed that Mr. Bernays had introduced

twelve steel pins into his clutch. Those pins had of course been put in to make certain that they could always shift the pulley round only one-twelfth, so as to provide for difference in the rope. Were the pins calculated so that any one or any two of them would be sufficient to drive, or was it expected that the whole twelve were to take the bearing? That kind of pin-work was generally very treacherous. Some years ago he had occasion to drive a helve hammer at an ironworks under rather peculiar circumstances. The shaft off which he had to drive it ran too fast to permit the use of four or six cams, and there were two cams only on the lifter. The consequence was that there was danger from the cams striking the helve hammer toe at too high a speed and breaking the shaft, or breaking the toe, or coming to grief in some way or other. To get over that disadvantage he introduced a system of indiarubber buffers, so that they took the shock in the first instance. There were four large pins for driving. The hammer and the buffers stood very well, but he never could get the pins to stand. They would invariably sheer across or give in some other way. If the pins mentioned in the paper were calculated so that any one or two of them would do the work, he could understand that they might answer very well, but if they were dependent upon the bearing being extended over a number of them, he should doubt very much whether they would answer.

Mr. T. Sopwith said that he was interested in the question which had been raised by one of the speakers as to the arrangement of the winding engine. It seemed to him it was unnecessarily complicated, and that the intermediate shaft might have been dispensed with. He had been trying to learn the advantage of having two winding shafts (or pits) to the mine. He should have thought that any quantity of stuff could have been drawn up one shaft of 14 feet in diameter from the moderate depths of a mine like San Domingos; but possibly Mr. Bernays had a special reason for the second shaft, and could give a satisfactory reply. As to the detail in Fig. 15 he thought that the action with the loose drum was not the cheapest that could be applied. In drawing smaller weights than those which Mr. Bernays had to deal with, he (Mr. Sopwith) had found it sufficient to have bosses upon the arms of the two drums, and a long pin passing through the bosses, being near the periphery of the wheel, where there was not so much leverage and strain as must come upon the pins when placed as in Mr. Bernays' arrangement near the centre. In such arrangements he had generally had three or four pins

passing through. They were merely block pins off the hammer, passing through the bosses. He had found, practically, that the men generally drove without accident with only one pin. In point of construction, he should consider that the arrangement he was in the habit of using was about 40*l.* cheaper in the cost of a drum of the size shown in the drawings than Mr. Bernays' design.

Mr. John Walker asked if Mr. Bernays would give some further information with respect to the catch gear. He did not clearly follow the description as to the peculiar arrangement of catches. As to the boilers of the winding engine, he did not know that there was any peculiar advantage in the construction which Mr. Bernays suggested. When he (Mr. Walker) had a Lancashire boiler made, he generally had the horizontal joints of the first, third, and fifth plates made in the centre of the second and fourth plates. In the setting he always caused the flue at the back to descend, and if he had a double-flued boiler, he used two dampers. He adopted that setting eighteen years ago, and with good results.

Mr. Joseph Bernays, in replying upon the discussion, gave a further description of the catches as requested by Mr. Walker. He then said, in answer to Mr. Pendred's remark as to the strength of steel pins, that the pins in the clutches which he had described were made of Bessemer steel, and they had been calculated so that two of them should carry the load. The clutches had been manufactured very carefully, the pins being carefully bored and turned. He personally tried each pin in the twelve holes, and they came exactly right and would always work together. Mr. Horsley had objected to the small size of the pulleys. They had had a great deal of experience with small pulleys at the mines in Portugal. The usual steel and iron ropes were about $1\frac{3}{4}$ inch in diameter, being very heavy, and were used in the incline tunnels, where the loaded trucks had to be pulled up an incline of about three or four to one. For these ropes they had pulleys of not more than 7 feet in diameter. He had made inquiries about the wear of the ropes, and he had found that to enlarge the gearing and to put in heavier pulleys would cost considerably more in the mere annual expenditure than would be saved through the reduced wear of the ropes. They knew what the rope cost and they knew how long it would wear; and they had found that the saving which might be caused in that direction by substituting larger pulleys for the 7-feet ones would not equal the interest on the capital which would have to be spent in making the change.

There were also other considerations. The mines were out of the way, and the cost of the freight had to be taken into account, and that was one of the reasons why the whole affair was designed to be within reasonable proportions. The ropes that were now to be used were only $\frac{3}{4}$ inch thick, so that they would work very easily round the 11-feet drums. The speed of the drums would be very much less than the speed they were accustomed to in this country. The greatest depth would be something like 130 yards, and the mines were not being worked at the greatest depth at present. The drums would pull up the cages in about ten revolutions, and the engines would make about thirty revolutions per minute, so that the ascent would take rather more than a minute from the average depth. He had been in shafts where very heavy engines, with drums of 30 feet in diameter, were used, the engines being geared direct to the drum shafts. In one case which he had seen they pulled the cages up at a speed of about 60 miles an hour (or say 5000 feet per minute). He was only working them at about 360 feet a minute. The ropes had therefore time to adjust themselves over the pulleys very comfortably, and the ropes being very small in thickness, he believed that they were perfectly safe and quite sufficient for the purpose. Another thing to be considered was the price. The big engines and big drums cost an enormous amount of money. In his own case the complete weight of the indoor gear, including the countershafts, drums, wheels, and all that belongs to it, and also the overhead pulleys and the other arrangements between the engines and the shafts, was 75 tons; the pair of engines weighed about 30 tons; the three Lancashire boilers weighed 40 tons; the cages and catches weighed 17 tons together for four sets of catches at two different landings. Thus there was altogether about 162 tons of material. This cost, complete and delivered in dock in England, including packing and management expenses, less than 6000*l*. The intermediate shaft was a mere expedient to enable them at a future time to put on another set of drums, which it was expected would be required, and for which there was plenty of power.

He had been asked why he pulled up such a heavy load at one time, instead of only a ton or a ton and a half. He had already explained in his paper that the same trucks which were filled underground and brought to the surface were sent down to the port, a distance of 12 miles, without being unloaded. This arrangement was so good that he had not disturbed it, and it avoided cost in the way of labour, and waste in charging and in discharging. It had been thought unnecessary to have

safety arrangements, because the engines were perfectly under control; and as the engines worked very much faster than the drums, the former could be allowed to go round half a revolution without in any way endangering the lift. The whole circumference of the drum was about 35 feet, and the engines would have to make 5·34 revolutions to raise the cage that amount, but as the headway between the brace and the level of the ground was about 40 feet, we might surely expect that no driver would be likely to let his engine run away to that extent. His reply as to the weight which was raised at one time would also answer the question as to the size of the shaft. It had been found by calculation that it would be cheaper to make two smaller shafts, than one shaft large enough to allow two trucks to run side by side. The sectional area which would have to be dug out of the one large shaft would be greater than that of the two smaller ones.

Mr. Sopwith had mentioned his arrangement, in which he preferred to have the disconnecting pins near the outer diameter of the drum. He (Mr. Bernays) had explained in his paper that the work from one level to another would have to be done several times a day. There was one operation to pull the clutch out of gear and push it into gear again. It was thought to be the simplest plan to have a central clutch, just as in any other gearing. The only question was how to construct it strongly. As to the construction of the boilers, which had been referred to by Mr. Walker, the usual way was to have the alternate longitudinal seams in one line all along the boiler. His (Mr. Bernays') arrangement was that the alternate joints changed by a few inches, and did not run in one line, for of course the longitudinal seam was the weakest part of the boiler. They all knew that the longer a flue was, the weaker it was to outside pressure. So it was with a boiler, with regard to the inside pressure; to shorten the weakest part at any point was to strengthen the boiler. In his arrangement he had shifted the seams so that they were not all in one line. For instance, the first seam was not level with the third seam, and again the fifth seam was shifted a few inches beyond the third, so that in no horizontal section would there be more than a short length of seam. He should have liked some gentleman to say something about the ropes, and how to test them efficiently and simply.

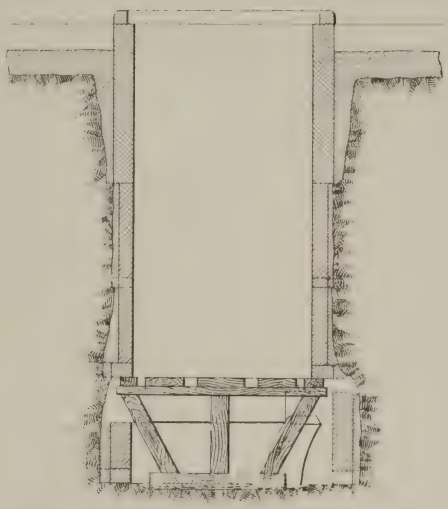
Mr. F. T. Barry, of the San Domingos Mines, said he thought it was right that he should upon the present occasion offer his

thanks to Mr. Bernays for the very efficient way in which he had carried out every engineering detail which the proprietors of the mine had referred to him. Going back to the commencement of the mine, he was afraid that the origin of it had been a little too highly coloured, for reference had been made to their having begun with mules and horses, whereas they really began with donkeys. The result of progressing from donkeys to locomotives, and then to the very excellent machinery which had been explained by Mr. Bernays, was that in twenty years they had laden over 7000 ships, ranging from 150 to 1000 tons burthen. They had brought over and sold in this country two and a half millions of tons of the mineral, and their total gross sales had reached between seven and eight millions sterling. Out of those seven and eight millions they had managed to get a little profit. He should not say how much. He hoped that in the future when the new machinery came into operation, and they were able to raise more mineral, their profits would be proportionally increased. They were now raising about 1000 tons a day.

The President observed that both the paper and the discussion had been very interesting, and the Society had become indebted to Mr. Bernays for much practical information. One thing which had struck him with some degree of force, was the remarkable way in which great results often arose from very small beginnings. In the present instance the adventurers had begun with very rude huts to shelter the workmen, and with animal power for carrying the mineral. Then in time carts were added to the animals. Then by degrees the mines were developed, and at last a very important industry had been secured, and had given rise to the employment of locomotives and the building of houses, schools, and chapels for the workmen and their families. With regard to the final results, their value depended upon the economical application of skill and labour. The paper and the discussion upon it had, however, fallen short of bringing out what he called the crucial test, which he might put thus: "What does the ore cost to raise, and what it is worth when it is raised?" Those were the two questions to which he should have been pleased to hear an answer. It was too late to ask Mr. Bernays whether he considered those two questions to be within the scope of his paper, but they were questions which must be applied to all industrial occupations. He took it that at the San Domingos Mines the mineral existed within easy reach, and that those who had

dealt with it on the spot had to compete with similar works in other parts of the world; but whether that was the case or not there still remained the vital questions to which he had referred, and upon the answers to those questions depended the value of all the operations which had been carried on and so lucidly explained.

Fig. 8.



g. 5.

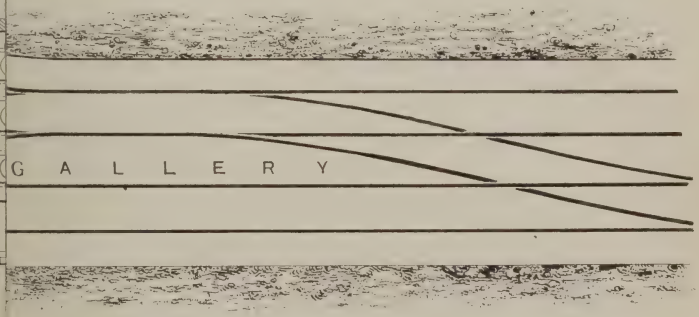


Fig. 1

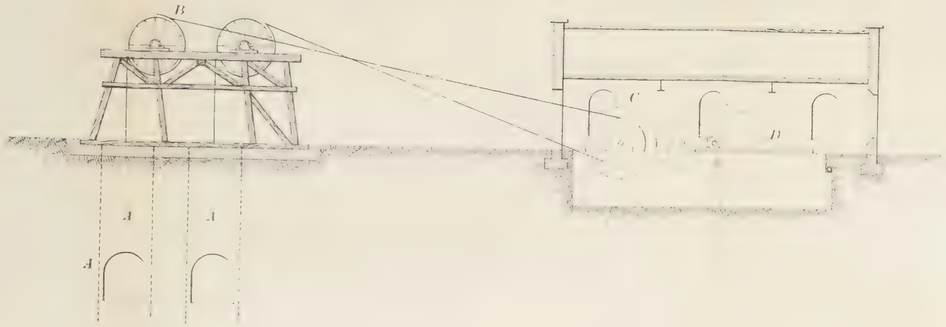


Fig. 2.

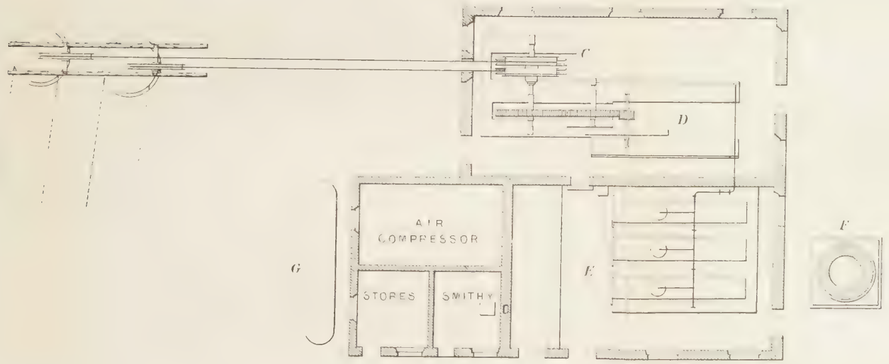


Fig. 3.

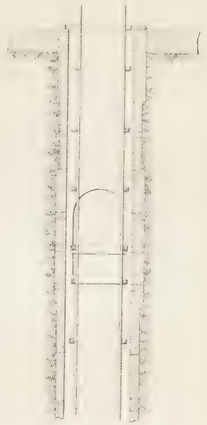


Fig. 4.

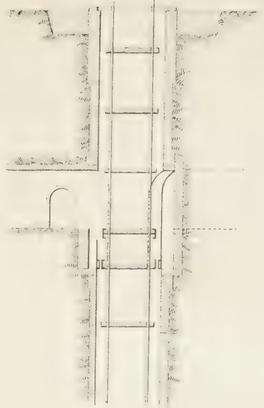


Fig. 6.

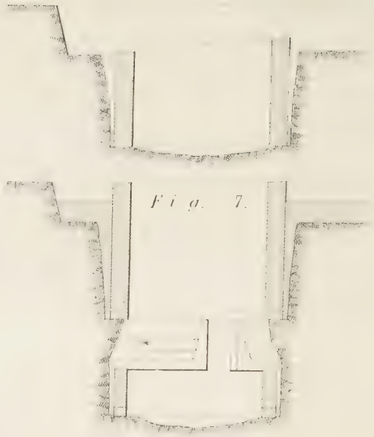
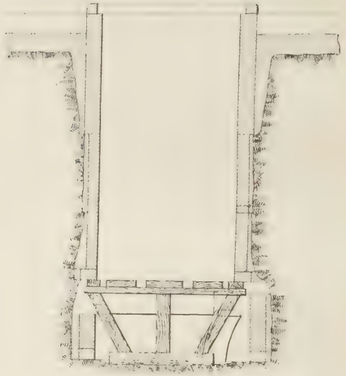


Fig. 7.

Fig. 8.



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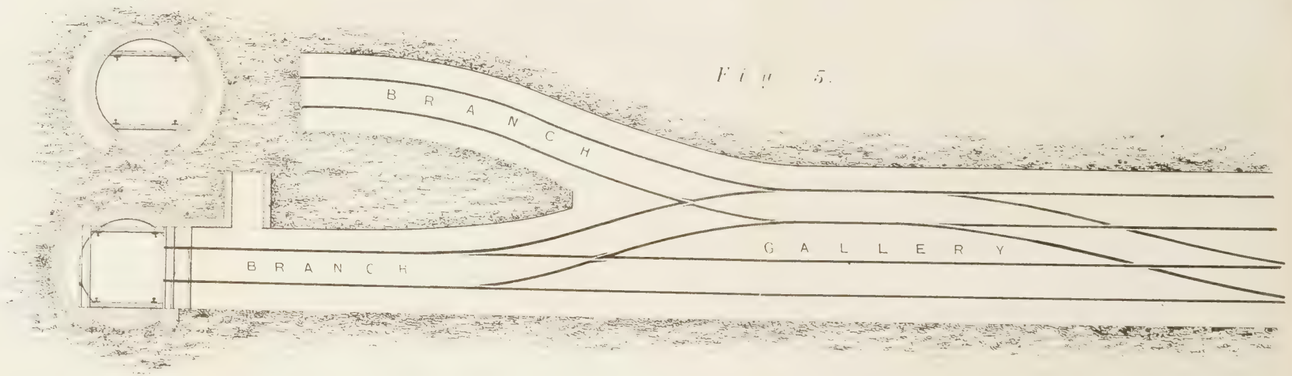

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Fig. 12.

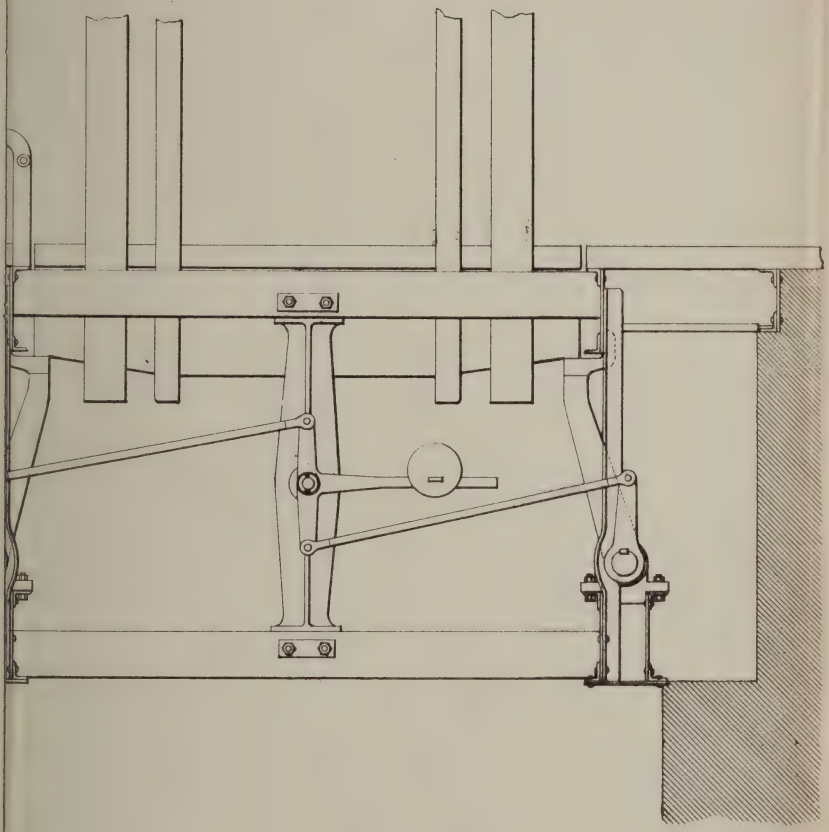

Fig. 9.

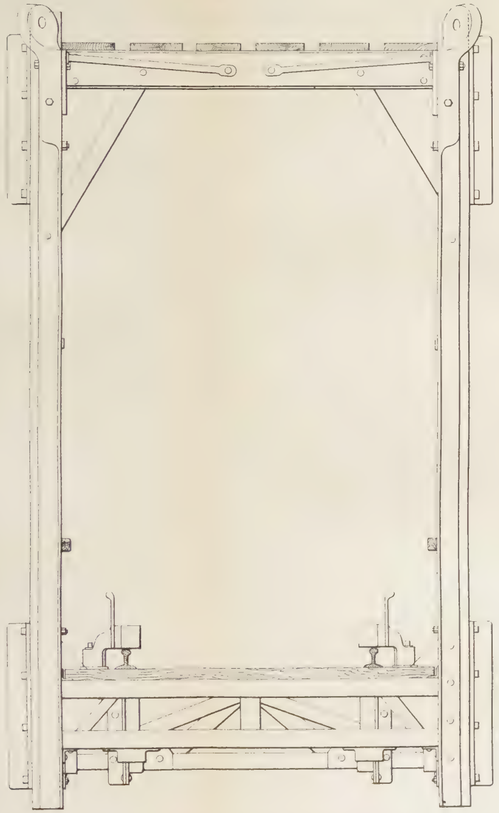

Fig. 10.

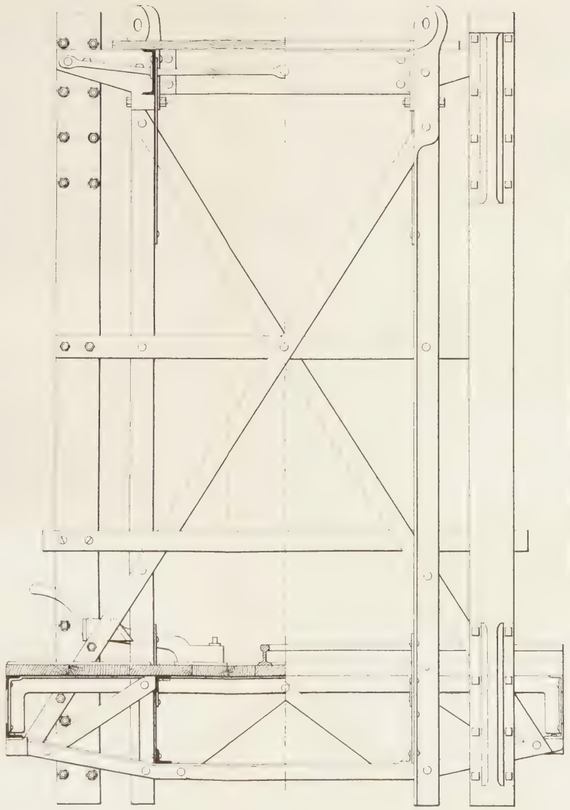

Fig. 11.

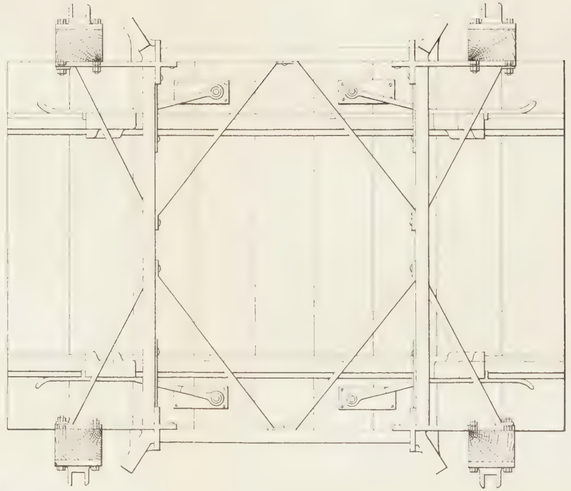

Fig. 12.

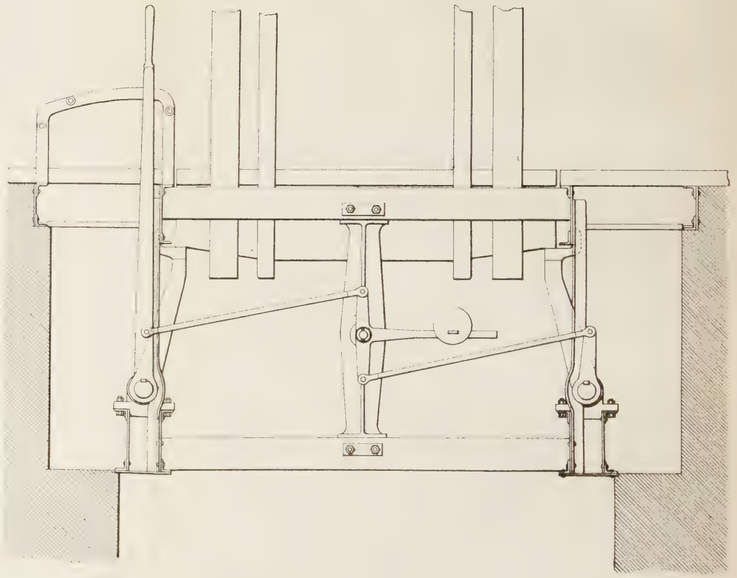

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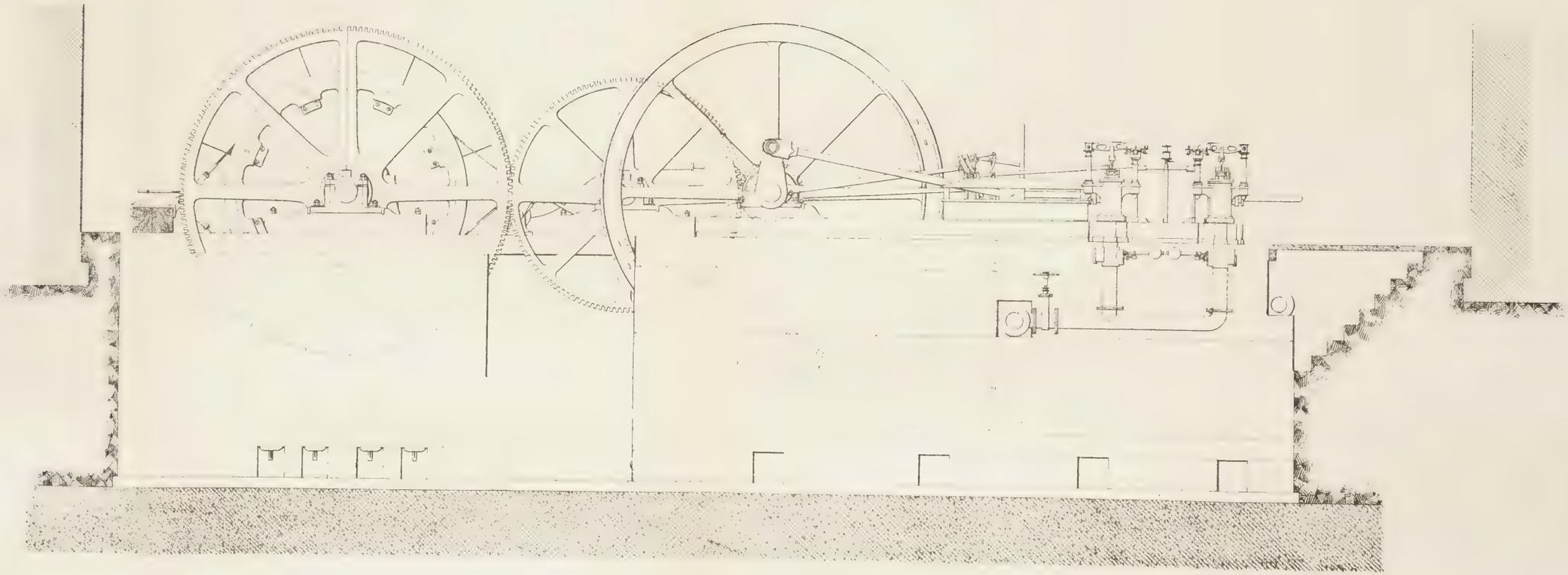
Plate 5

Fig. 12.



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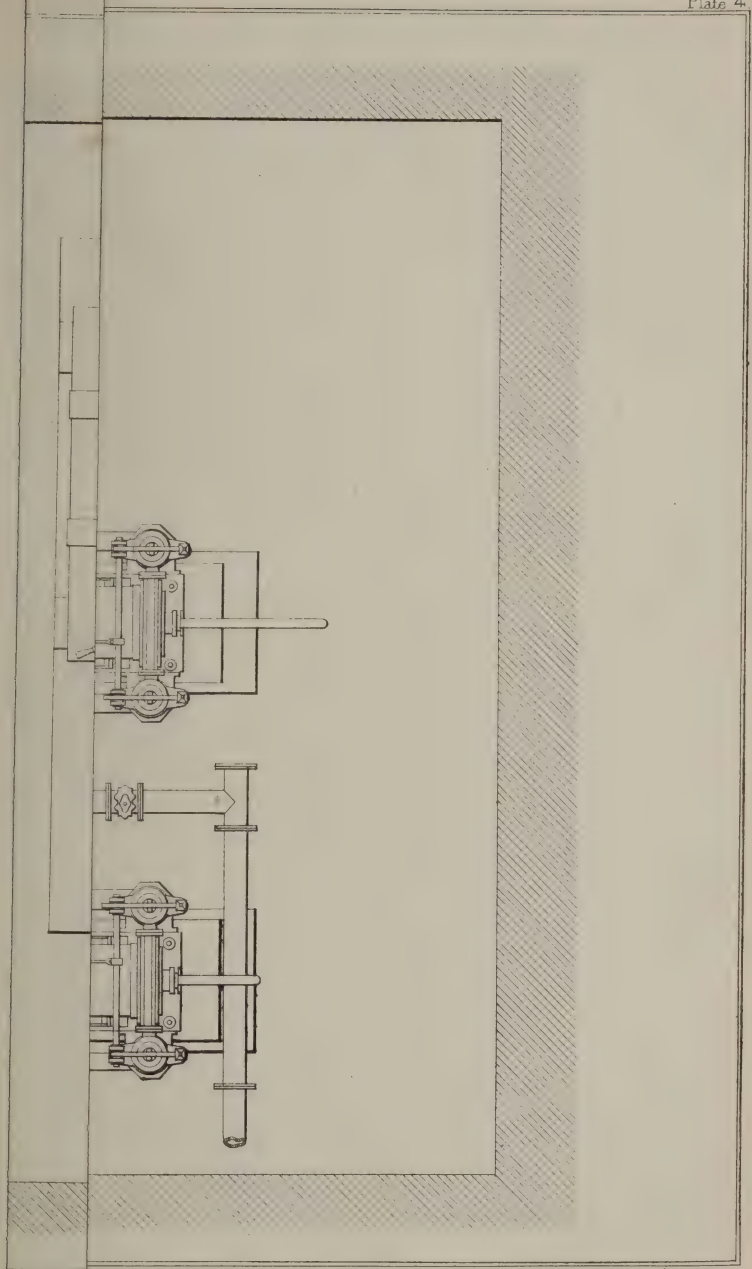


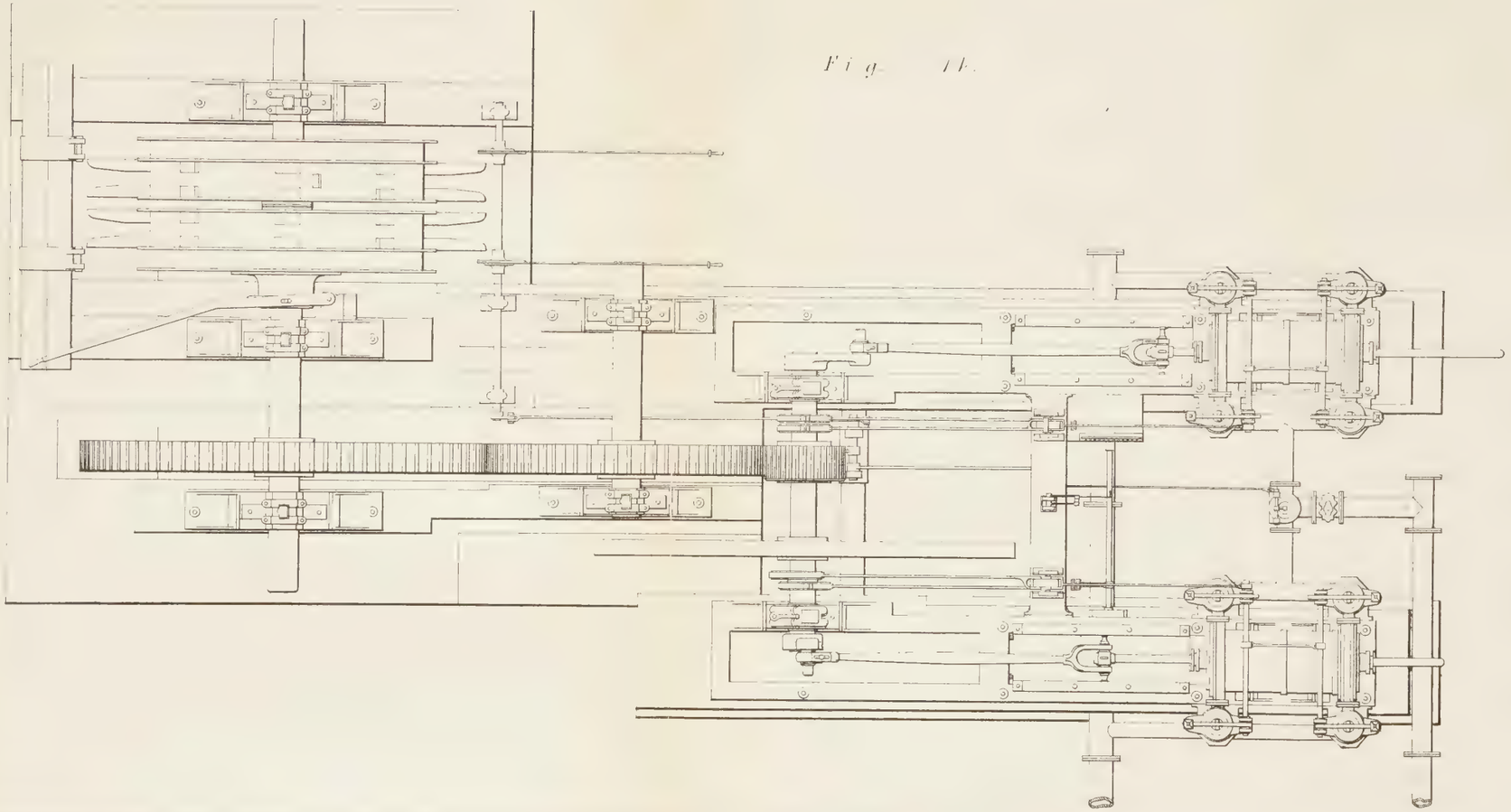


Fig. 11.

Fig. 15.

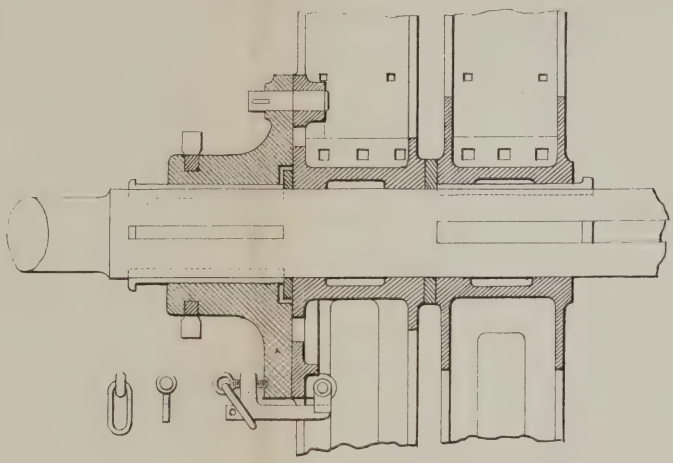
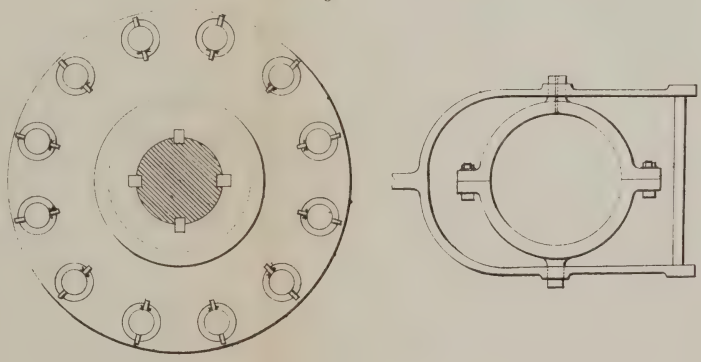


Fig. 16.



E. & F. N. Spon, London, & New York.

April 7th, 1879.

ROBERT PAULSON SPICE, President, in the Chair.

MODERN MACHINERY FOR PREPARING MACADAM FOR ROADS.

By Charles E. Hall.

The author is not aware that any attempt has hitherto been made to collect and put into readable form information of a reliable character, respecting the use of machinery for preparing macadam for roads by different persons under varying conditions, and in various parts of the country during the past ten years. Neither has he met with any classification of the different systems for effecting this purpose, or any record of the results from each, and this must be his apology for introducing the subject to the members of the Society. That it is of sufficient general interest, is proved by the constant legislation upon questions affecting our highways and the laws relating thereto. Altered conditions of trade and increased traffic have demanded an improvement in the construction and regulation of our roads, and more especially with regard to their maintenance in a state of general efficiency. The traffic is now very much heavier than in former years, whilst competition on every side requires that our rates of carriage should be considerably modified. This can only be accomplished by two known means: the first is the more extended use of steam on common roads, dealing with heavier trains of goods, whilst the second is the employment of ordinary horse traction, and very materially improved highways, so as to enable the same horse-power to double its carrying load by a corresponding reduction in the resistance due to gravity. The difference between a properly constructed and efficiently maintained road, and a badly constructed and neglected one, is as much as 50 or 60 per cent. on the item of haulage alone, or in other words, the same horse will draw over a good road a load of one ton with as little expenditure of force as it could haul 10 cwt. upon a bad one. This fact being admitted, it is not difficult to comprehend the progress that has been made in the construction and maintenance of roads, and the efforts which recent legislation has made to improve their regulation and control.

The enormous amount of macadam produced yearly by machinery, and the steadily increasing demand for it are proofs that the efforts of inventors have been recognized; but it is only within the last few years that any successful attempt has been made at producing a cubical sample of stone. In the earlier days of its introduction all efforts seemed to be concentrated upon the production of a machine which would deal with the largest quantity of material per day, irrespective of quality, and in this respect the Blake stone-breaking machine stood unrivalled. Quantity is certainly an enormous factor in the cost of production and should not be lost sight of in improving the quality; but the former must be sacrificed to some extent, as the author will show by an examination of the various systems now at work. This will necessarily lead to a determination of the special points to be accomplished in order to produce good macadam by machinery.

Hitherto the matter has been one between rival manufacturers, with no satisfactory means of indicating to the purchaser why this or that system was most suitable for his work, and the lack of information upon this point has frequently caused failure where success should have been certain. It is not a little curious that the best macadam is produced by those who make its supply a business, such as the quarry master, whilst individuals, corporations or local boards, who have their own machines, frequently make the worst. There is still a wide distinction maintained between machine and hand-broken stone by surveyors, although instances are not wanting in which they have discontinued the use of their own machine, and have purchased road metal from quarry owners who use a similar one.

Whilst admitting generally the superiority of hand-broken stone, the whole instincts of modern civilization teach us that such labour is degrading. After we have admitted that it is honest toil, we are apt to associate it with the last state to which a man can be reduced ere he departs this life, and we are not surprised at its adoption in our prisons and workhouses as the labour test, for such it is from its very nature, and the mind recoils from the contemplation of human beings suffering for years by its imposition, instead of being employed in less degrading occupations.

The object of road trusts and highway boards being to maintain the highest efficiency of their roads by the cheapest possible means, and having to deal with very large quantities of material spread over a still larger area, the author believes that he will best attain the objects aimed at in this paper by at once proceeding to describe the various machines at work and most largely in use, without attempting to enumerate all the

inventions which have been submitted to the public. The first upon the list is the original machine invented by Eli W. Blake, of New Haven, Connecticut, introduced into this country by the late Mr. Marsden, of Leeds. In this stone-breaker no attempt was made at cubing the material. It was simply a crusher of the most powerful kind, and capable of any amount of work. The first machines were constructed with the fulcrum pin of the moving jaw at the bottom, as shown by the dotted lines in Fig. 1, which is an elevation in longitudinal section. The corrugations S S in the jaws B and I are vertical, and interlock each other, as shown at Fig. 2 (which is a plan) from top to bottom, and prevent the stone from turning over. The arrangement, moreover, of centering the jaw from the lower end G instead of at the top G 1 was very disadvantageous from the fact of its having three times as much more motion at its upper end, where the stone is fed into it, than at its lower extremity, where it is discharged. The result was that the jaws became choked, and the stone was subjected to a large amount of unnecessary crushing, which produced much waste, and increased the power required to break a given quantity as compared with the action of the same machine when the vibrating jaw was hinged at its upper end, as shown at Fig. 1.

The first attempt at producing a superior sample of road metal was an adaptation of the Blake machine by Mr. Thomas Archer, jun., of Gateshead-upon-Tyne; but, as the author believes there is not a machine in use at the present time upon this plan, it need not be further referred to, and he will therefore proceed to describe Mr. Archer's more original machine of 1867 (see Fig. 3). This is shown by an elevation in longitudinal section, and consists of a main cast-iron frame A, with a slotted crank shaft C running in bearings at the end of the machine, operating a large lever or squeezer B, whose fulcrum pin is at F. The rear end of the lever was connected to the crank by an alterable link D, which controlled the position of the crushing faces H and G in relation to the rotating roller I, so as to produce finer or coarser macadam. The front end of the lever was made curved, to partly encircle the roller I, and was provided with corrugated faces H and G in the upper and lower jaw. The teeth in the roller I were at right angles to those in the lever B, and the stone was gradually fed between the two, by the slowly rotating motion given to the former, against which it was broken.

This machine involved two correct principles for cubing stone, but it has failed in practice to stand the test of continued work. It produced a fairly good sample of macadam with as little waste as the Blake machine, but could never compete

within 30 per cent. of the amount of work done in a given time for the same power, whilst the friction, wear, and tear, and breakage were very much higher. The chief fault here lies in the application of its motive power, for the first principle involved in the construction of a good stone-breaker is wanting. This experience has decided to be the maintenance of the strains in one direction only. They should never be reversed or affected by wear, and be simplicity itself. The use of spur gearing shown at Fig. 4, which is a plan, to rotate the roller is highly objectionable, as the excessive vibration set up by the alternate action of the squeezer upon the periphery of the roller rapidly destroys it, and renders the machine unfitted for the rough usage met with in quarries.

About the same time Messrs. Smith and Roberts were introducing a lever crusher of a very much simpler and more powerful kind for reducing limestone, &c. for chemical purposes. This is illustrated at Figs. 5 and 6 by an elevation in longitudinal section and plan, and is the property of Messrs. Kneeshaw and Lupton, whose quarries are situated at Port Nant in North Wales. It is used upon a hard tenacious granite, which is one of the severest tests the author has seen. Early in 1878 Messrs. Kneeshaw and Lupton consulted the author as to the possibility of constructing a machine upon this principle for producing macadam by adopting his plan of crushing and cubing faces, and after a few experiments the machine was made by the Savile Street Foundry and Engineering Company of Sheffield from his drawings.

It consists of a huge frame A (Figs. 5 and 6), with a slotted crank shaft C at the rear end, revolving in bearings L L, with two massive fly-wheels G, and driving pulley thereon, and an adjustable connecting rod D for regulating the size of the broken stone by opening or closing the jaw F F. A lever B, with its fulcrum pin E, vibrates between the sides of the main frame A, and is coupled to the connecting rod at I by a cross-head and nuts at its rear end; the front end has upper and lower crushing faces F F F F, secured thereto by bolts. These faces work opposite fixed faces, similarly secured to the block J at the end of the machine; the angles of both sides are alike. Apart from the mechanism employed for operating the crushing lever the author would draw attention to the special arrangement for cubing the stone. It will be observed that the upper faces project considerably over the lower ones and are of coarser pitch, each tooth works into the furrow immediately opposite, where the stone is first sledged, and when sufficiently reduced it falls between the lower faces, whose teeth are set immediately opposite each other, and are of a finer pitch. Here it receives

a final nip and is broken into a more cubical state. The stone in its passage downwards, however, becomes turned over and crossed, often several times; the action of the lower faces is also more of a cutting kind than in the upper ones.

A vibratory motion is imparted to the lever B by the revolution of the crank shaft C, the stone is alternately broken at the top and at the bottom. This divides the strain upon each half revolution of the shaft, but introduces the highly objectionable reversal of strains through all the moving parts. To obviate this evil the author adopted extensive wearing surfaces and adjustable bearings. Another serious drawback to the use of a crushing lever, such as Archer's and Smith and Roberts', is the central part of the face opposite E, where the motion changes; here there is a tendency to resist the descent of the broken stone to the lower jaw, and consequently a liability to choke. This was effectually got over by the enlargement of the throat or swallow X, a point which deserves as much attention as the relative stroke of the upper to the lower jaw. This machine does a fair amount of work of a good quality, and as it may be said to combine the property of two machines in regard to its operation on the stone, it is much superior to the Blake in that respect.

Another arrangement which was adopted by Messrs. Ord and Maddison, of Darlington, is shown at Figs. 7 and 8 in sectional elevation. It consists of a 20 by 9 inch Blake machine worked in conjunction with a pair of corrugated chilled rolls L L, placed conveniently near so as to receive all the large pieces of stone that will not pass through a 2-inch ring. One of the rolls is corrugated in the direction of its length; the other circumferentially, so as to act at right angles, with the object of crossing the flakey pieces as they come from the Blake machine, by which method a fair sample of road metal is produced so long as the rolls remain in a good condition. Too much gearing has, however, to be used in reducing the first speed, and multiplying the power sufficiently to deal with the excessively hard trap rock and boulder whinstone of their quarries. The system has been in use by the firm named for some years, and has seen a large amount of service, but it has never been a favourite with quarry owners, as it does not fulfil the conditions required of a really good stone-breaker.

Another system not illustrated has been adopted by Messrs. Winn and Son, of Great Ayton, in North Yorkshire, for breaking whinstone. It consists of a 20 inch by 9 inch Blake machine, which is used to break down the stone to the desired size, and after passing through a rotating screen the rejected or large pieces which have escaped the first jaws are dropped into

the mouth of an Archer machine of much smaller capacity. This saves the cost of a boy breaking the rejected stone, or of returning it back to the original machine, which is now the custom at some places. The arrangement answers well so long as the Blake machine does the hard work, but it is not one that commends itself at the present day.

Close to the Great Ayton Quarries is to be seen another combination by Mr. Marsden, of Leeds, in which a 20 inch by 9 inch, and a 12 inch by 5 inch Blake machine are used in a similar manner to the foregoing. The first machine is set with the jaws wide open so as to allow about 25 per cent. of the material to pass through in order to feed the smaller one at the end of the rotating screen, which is 16 feet long, and has four or five different sized holes for the classification of the road metal. This is an important point in connection with the production of a good sample, and is specially suited to the requirements of a corporation like Leeds, to whom the quarries belong, and who have extensive roads to make and repair with such a diversity of traffic upon them. The plan is, however, but an admission of the principle which the author strongly advocates where machines are fixed in quarries. The second machine should be equal in width at the mouth to the first, and of the same capacity, allowing fully 60 per cent. of the material to pass into it, the first machine being used solely for sledging the stone, whilst the second is employed in cubing it; the final classification taking place beyond the latter machine.

Another system, and one which to the author's mind possesses many advantages, is that adopted by Messrs. Bradley, of Great Ayton, for breaking whinstone. It is the invention of Mr. Madderson, engineer at the quarries. The author believes that several years' practice has proved it to be fairly successful, both in the quantity and quality of work produced; it possesses, however, the great disadvantage incident to all lever machines of having an alternate action upon the jaws, in rapidly reversing the direction of motion, which is, at high speeds, so objectionable when subjected to excessive strains. At the time of its introduction it may be said to have stood unrivalled. By referring to Fig. 9, which is an elevation in longitudinal section, an accurate idea of its construction may be ascertained. A heavy cast-iron frame A is made to receive two distinct vibrating jaws K K similar to the Blake jaw; one disposed above the other, of the same width, and with teeth of the same pitch, working with their ridges into the opposite furrows all the way down. The mouth of the upper jaw is 20 inches by 9 inches, that of the lower 20 inches by 6 inches. The fixed jaws I I I are secured to the end of the frame, and are separate, but their

face is in the same vertical line, as also are their teeth; the upper vibrating jaw is worked about 3 inches open, thus all the stone passes to the lower jaws, where it is finished to the required size, and passed into the screen, where the various sizes are separated. The stone has thus a clear drop of at least 12 inches from the acting surface of one jaw to the other at X, by which it will be seen that it is turned over and allowed to readjust itself before being finally broken by the lower one.

The upper jaw K simply sledges the stone, whilst the lower one K cubes it. The mechanism for working them consists of a massive lever B, working upon a fulcrum pin H immediately behind the toggles G G, which are alternately pushed forwards and drawn back by the coupling rod M M and indiarubber springs N N, secured to the lower end of each jaw and the lever B. A connecting rod C, worked by a slotted crank E, revolving in bearings at about 220 revolutions per minute, communicates a vibratory motion to the lever. A pair of massive fly-wheels P, with a driving pulley, are secured to the shaft, the connection being made between the upper and lower ends of the lever and the upper and lower jaws by the toggles G G, the strain is divided between each half revolution of the crank shaft E, and, unfortunately, reversed. All the shafts and bearings liable to wear have brasses and keeps which can be taken up.

An elaborate system of crushing rolls and massive gearing, with automatic arrangements in the form of iron creepers for feeding the rolls, is adopted by Messrs. Ellis and Everard, of Markfield Quarries, Leicestershire. The breaking is done by passing the stone through several pairs of rolls with teeth of various pitches, and set at different widths apart, until it is reduced to the required size. The greatest care is exercised in feeding these machines, and the stone is quarried rather small so as to give the machinery the best possible chance of producing metal of a good quality with as little waste as possible. The system is too costly, and the wear and tear too great, to be within the reach of any one but the proprietors, who have studied the matter attentively for years, and, being pledged to a system, appear determined to carry it out. The principle of breaking down stone by degrees, and of classifying it each time, is the correct one; but carried out on such an extensive scale it is deprived of that simplicity which is alone the essence of success, commercially speaking.

At Mount Sorrel and Croft, in Leicestershire, Blake's machines with crushing faces, designed by the proprietors of the quarries, are worked in combination, or rather in conjunction with toothed rollers which receive all the rejected stone from the ends of the screen. The rolls are rotated by powerful spur

gearing, and are either composed of rings of teeth or one solid roll, formed with hollows and projections.

The next machine upon the Blake plan which gave prominence to special arrangement for cubing the stone, is shown at Figs. 10 and 11. It is called the "Excelsior" stone-breaker, and was invented by a Mr. Hope, of Australia, and introduced into this country about the year 1872. The chief point of difference between the jaws of this machine and Blake's is in curving backwards the vibrating jaw K at X; the teeth are of 3-inch pitch and continuous from top to bottom; the fixed jaw I has the teeth upon its upper portion working in the furrows of the opposing jaw, best seen in the plan, Fig. 11. Towards the bottom end they are discontinued and others placed between the furrows, so that these teeth work opposite the teeth in the vibrating jaw K, making a square hole through which the stone has to pass, and is therefore subjected more to a clipping than a crushing action, as when the tooth works in the furrow. The lower series of teeth are also projected forwards to meet the retiring vibrating jaw so as to prevent long pieces which have been sufficiently reduced one way, from passing out. This arrangement makes no provision for turning the stones over or giving it a chance of readjusting itself whilst in the jaws, and is therefore very defective. Very great results were expected from this machine, but the author has met with very few at work.

The mechanism for operating the vibrating jaw is also novel and will be seen by a reference to Fig. 10, which is an elevation in longitudinal section. It consists of a nearly vertical lever C, between which and the back of the vibrating jaw is a toggle plate F, the other side of the lever rolling upon a pin G fixed in the wedge block H. Motion is communicated to the lever C from a crank shaft D, rotating in bearings in the main frame A by a coupling link E, lined with adjustable brasses. Two massive fly-wheels P and a driving pulley O are furnished, which rotate 250 times per minute.

The next attempt to cube the stone was made by the late Mr. Marsden in his Blake machine, and diagrams of the jaw faces are shown at Figs. 12, 13, and 14. Fig. 12 is a vertical section through both jaws. Fig. 13 is a plan and Fig. 14 a front view of the face, the other face being the exact counterpart so as to work tooth and space. The difference between Mr. Marsden's cubing jaw and the Blake jaw consists in the addition at its lower end of a series of teeth, each row being alternately ridge and furrow, and working opposite a fixed jaw similarly formed; and in diverting the vertical and angular line of the face backwards and forwards, but always parallel;

the idea being that as the stone descended, it would engage with either one series of teeth or the other, and be turned out of a more regular size and even shape. This was so to a large extent, but the process so limited the output of the machine, and produced so much dust and waste that few machines were ever constructed upon the plan; Mr. Marsden wisely contenting himself with the addition of one bend instead of three, and one alternation of the teeth, more after Mr. Hope's plan, but working the lower series tooth and space. The machine is shown in section at Fig. 12 and consists of a main frame A in one piece with a vibrating jaw B, working on the fulcrum pin U and breaking the stone against a fixed corrugated face I. An eccentric shaft D operates a massive connecting rod C, upon either side of which are the toggle plates F F, resting in grooves in the jaw B, connecting rod C, and toggle block H. A wedge G sets forward the jaw, or takes up any wear upon the toggle ends. Two massive fly-wheels P, with a driving pulley O rotate the shaft D, and vibrate the jaw B, about 250 times per minute. A rod L and an indiarubber spring M bring back the jaw at the completion of its stroke. The machine has been extensively adopted, and years of practice have proved the superiority of the toggle principle over any other for securing a powerful, noiseless, and lasting means of transmitting the tremendous crushing force necessary for reducing large lumps of stone.

Turning now to Figs. 15 and 16, we have Archer's last effort at breaking and cubing stone for road purposes; the original machine having passed through many vicissitudes before this result was attained. It consists of a short Blake vibrating jaw B, suspended upon the fulcrum pin U secured to the main frame A, working opposite a fixed face I, the teeth are set ridge opposite furrow; below this is slowly rotated the horizontally-toothed roller L, against which works a vibrating lever C with a curved face K; the teeth being at right angles to those on the roller. The lever C vibrates upon the fulcrum stud G, passing through the sides of the frame, and is operated by a slotted crank shaft D running in adjustable bearings at the rear and coupled to the lever by an alterable link E. Two massive fly-wheels P and a driving pulley O give motion to the jaws at a speed of about 220 revolutions per minute. At V V two steel bars are let into the lever and jaw to press forward the Blake jaw B, whilst a rod and an indiarubber spring withdraw it at the return stroke. Upon the crank shaft is another pulley R, from which a belt passes to the pulley Q, with a steel pinion S secured to it, mounted loosely upon the roller shaft M. This transmits power to the spur wheel T, which has also a steel pinion W secured to it, mounted loosely

upon the fulcrum stud G; this gears with the spur wheel X, keyed to the roller shaft and rotates it at the proper speed for delivering the stone as it is broken against it by the lever C and face K. The roller maintains a continuous rotatory motion, but it is evidently subjected to two opposite and destructive actions at the same time, which tell seriously against its life, and to which there are grave mechanical objections. Intermittent motions have been attempted by Mr. Archer to obviate the difficulties, but the author believes without success.

Several other inventions have been proposed from time to time by inventors for breaking stone; but as none have been successful in practice, the author need not further refer to them, but pass at once to an improved machine invented by himself in 1876, which is represented at Figs. 17 and 18.

In the longitudinal section, Fig. 17, it will be observed that the distinctive features of the Blake machine have been retained, whilst the difference, or "multiple action," as the author terms it, will be best seen in plan, Fig. 18. This consists in splitting up the jaw B, connecting rod D, and toggles E, into two distinct sets, operated by one eccentric shaft C with two eccentrics forged thereon at opposite centres, so that they work alternately. In this way the whole of the moving parts of the machine are placed in perfect equilibrium at all times. The strains are reduced 50 per cent.; each half revolution of the driving shaft performs an equal amount of work, and the speed of the machine may be considerably increased; the vibration is greatly reduced, and the power required to perform a given amount of work is materially less.

The arrangement for returning the vibrating jaws B is also novel, the spring hitherto used in the Blake machine being dispensed with, and a positive mechanical draw-back motion substituted, which consists in coupling the working jaws B together by rods H secured to their lower end by pins, and carried underneath the machine to an equal ended vibrating lever L, mounted upon a stud secured to the back of the frame, so that the forward motion of one jaw causes the other to retire to the same extent at each revolution of the eccentric shaft C. The two rods are adjustable as to length by the lock-nut and washer M, to take up the wear, or for opening and closing the jaws for breaking different gauges of stone. The feature in this stone-breaker, so far as it concerns this paper, is the special arrangement for producing a more uniform and cubical sample of road metal than heretofore in one machine, without impairing its portability or handiness for general purposes.

Referring to Fig. 17, it will be seen that the vibrating jaw B has an upper and a lower face S S, separated towards the

centre and secured to B by a wrought-iron wedge and bolt T, so that either face may be readily renewed and reversed. The upper one projects considerably over the lower one, the fixed jaw-faces I are also divided into two, the upper one overhanging the lower one, and by preference the top faces have coarser teeth than the lower ones, in order to sledge the stone in thicker pieces and give greater freedom for its descent to the finer pitched faces below, which cube it. In all cases the teeth are straight from end to end, and the throat, formed at the junction of the faces, relieves the machine of considerable strain, allows the roughly broken stone to turn over, its readjustment being greatly facilitated by the alternate action of each vibrating jaw. The result is a very much more cubical form of stone without diminishing the output by causing it to change its direction as in all other cubing jaws. The teeth in the upper faces work ridge against furrow, whilst the lower teeth work ridge and ridge (see Fig. 18).

The faces are made of a special mixture of cast iron run upon chills, securing great hardness of the face, whilst the back is soft enough to be planed, so that their renewal is a very simple matter and quickly performed. To produce any desired size of macadam, the author recommends the lower faces to have teeth of the pitch represented by the size of the stone required: for a 2-inch gauge, teeth of 2-inch pitch, and so on.

Any one who has watched the action of a stone in a Blake machine whilst being broken will have observed that from the moment it receives its first crush, until it is delivered out, it follows the groove in which it happens to be; slowly descending as it is reduced, receiving all the blows in one line and at one spot, which action tends to splinter it into long, flat pieces, the stone is weakened by the repeated blows in the same place and considerable waste ensues.

The secret of producing a fair average quality, is in copying the hand process as nearly as possible. No one would think of breaking the stone all one way, but, after spalling it, would cross it so as to give an equal thickness each way, and the machine which can turn over the stone most frequently in its downward passage, whilst subjecting it to the action of the jaw, will produce the best road metal. The author has endeavoured to arrive at this result by the combined action of the advancing and receding jaw, and upper and lower faces, with the enlarged throat giving the stone freedom to turn over; this is proved by the fact that a stone placed at one side of the machine is very soon delivered over to the other.

Having now described the various machines in use for preparing macadam, the author will proceed to enumerate the

several features which are essentially necessary to secure anything like a cubical sample of road metal, no matter what principle is adopted for operating the crushing jaws in any machine.

1st. The stone must be sledged by an upper set of jaws and cubed by a second or lower set. This operation may be done by two separate machines working together; or in one, as in the author's plan; but the stone must have relief by an increased space, situated between the two processes, so as to have an opportunity of turning over or readjusting itself freely to be further operated upon.

2nd. It is better, where possible, to have a coarser pitch of teeth in the upper jaws, and to work them with the tooth opposite the space, than in the lower, which should approximate in pitch to the gauge of stone required. This is found to be 2 inches; the teeth in the lower section should work point to point in order to clip the stone rather than crush it, which often weakens it.

3rd. A careful classification of the various sizes of broken stone is essential to maintain a good quality; this classification taking place between the two machines as well as after the second one.

4th. A good speed, with a sharp blow and with bottom crushing jaws in good condition, that is, with sharp angular teeth.

5th. Strength, simplicity, and power. The strains and wear and tear should be always one way, and the working of the machine should not be affected by them. There should be no gearing, and practically no noise, which follows by keeping the strains in one direction only.

These points may be easily secured by any one who has given the matter thorough study, and especially so in regard to fixed machines; but the question is extremely difficult as applied to portable machines, such as are required by local boards or contractors, for these must make road metal equally as good under infinitely worse circumstances.

The author believes he has secured all these points, both in his fixed and portable machine, in a manner never before accomplished. The machine may be run at 300 revolutions per minute by the road side, when mounted upon its travelling wheels, without any vibration, and consumes considerably less power to do a given amount of work, and this is accounted for by the fact that in a Blake, or any other similar machine, there are three distinct forces at work at the same time, each operating with the fullest intensity when in the act of breaking the stone, which is not so in the author's machine. These are:—

1st. The force required to break the stone acting over double the area.

2nd. The power necessary to set in motion and lift the whole of the mechanism for operating the crushing jaw, which is very heavy; and

3rd. The power required to compress a spring, which must be powerful enough to return the jaw and motion at the completion of its stroke.

As to the best size of stone for roads, experience varies considerably; but the evidence supplied by quarry owners points to the 2-inch cubes as being most largely in demand, and stone of this size is doubtless the most durable.

At Fig. 19 the author has shown an arrangement which has been successfully adopted by the Clay Cross Iron and Coal Company, near Chesterfield, for breaking slag for road purposes. It consists of a 15 inch by 9 inch Blake's breaker A, with the jaw set wide open so as merely to rough break the slag as it is brought in the trucks from the blast furnaces; it then passes through a rotating screen E, where the various sizes of broken stone are classified. The largest amount passes to a second machine constructed under the author's patent by the Savile Street Foundry Company of Sheffield, from whence it is delivered into trucks ready for the market. The lower screen E has not yet been erected, the sample of material sold being considered good enough for the market. The second machine is wider at the mouth than the first, and the consequence is the stone has plenty of room to turn over and become cubed.

The sand or waste from the screens at F may be made to join into one shoot, and may be used either for mortar or fine concrete for paving; that coming from the screens at S is useful for gravel walks and asphalting footpaths; that from H, which is 1½-inch road metal, is suitable for repairing and roads, where the traffic is light; whilst the material from I, which is 2 inches, is used for the roads having heavier traffic upon them.

The following is the estimated cost of producing 22,500 tons per annum of 2-inch road material by the multiple action machines, as arranged by the author at Fig. 19.

MACHINERY AND PLANT.

	£	s.	d.
One 20″ × 9″ stone-breaker	200	0	0
„ rotary screen and gear	25	0	0
„ 20″ × 7″ stone-breaker	150	0	0
„ rotary screen and gear	25	0	0
„ 12-H.P. semi-portable engine, complete	320	0	0
Belting	20	0	0
Timber staging, troughs, &c.	30	0	0
Loose tools, plant, &c.	50	0	0
	£820	0	0

	£	s.	d.
Interest on £820 at 5 per cent.	41	0	0
Wear and tear, 15 per cent.	123	0	0
Depreciation, at 5 per cent.	41	0	0
Coal consumption, per day 10 cwt., at 15s. per ton, (250 working days)	93	15	0
Stores, oil, tallow, waste, &c., 2s. 6d. per day .	31	5	0
Labour cost, 1 engineman at 5s. per day; 2 machinemen at 4s. per day, and 1 boy at 3s. per day = 16s. per day	200	0	0
	530	0	0
Working expenses, sundries, and management ..	280	0	0
	£810	0	0

Annual cost, 810*l.*, or 8·64*d.* per ton, inclusive of management and working expenses.

The author is unable to fix definitely the cost of producing macadam by machinery, which shall be true in all cases, as circumstances tend very greatly to modify it. He finds from authentic sources that it ranges from 25 to 100 per cent. cheaper than hand broken, and the following table has been compiled from actual returns received during the past month, and may be relied upon. It shows the comparative results obtained with the various systems of stone-breaking machines described in the paper upon a variety of stone, and frequently under different circumstances. These returns are based upon the actual production of road material, extending over a considerable time.

Column A gives the kind of stone, and the district where found.
„ B, The size of the various machines at the mouth, or the sized stones they will take in.
„ C, The particular system or machine. The machines at Mountsorrel are constructed upon the Blake principle, but with special arrangements for cubing the stone designed by Mr. Hambly, in addition to the rolls, four machines being used to one set of rolls.
„ D, The gauge to which the stone is broken, all of which passes through a ring of the diameter given.
„ E, The quantity of road metal produced daily.
„ F, The proportion of good macadam produced, and called No. 1; of gravel, No. 2; and of dust or waste, No. 3. This latter is valuable for concrete stonework and facing generally.
„ G, The H.P. employed to do the work.
„ H, The cost of producing the machine broken stone according to practice, including all charges, except in the last example, in which management and office expenses are not included.
„ I, The duration of the jaw faces.
„ J, The cost of breaking the same stone by hand. In the examples given of breaking slag the returns show that the quality of the stone is materially improved by being put through the machine, as in hand breaking the men invariably select the soft stone and throw the hard or best out, whilst in the machine broken slag the hardest stone goes to it. It is worth more per ton, and in many instances it is preferred.
„ K, The selling price of the stone at the depôt.
„ L, The method of working the machine.

Cost of Machine and Hand Broken Stone for Macadam.

A Kind of Stone, and where found.	B Size of Machine at Mouth.	C System, or Maker's Name.	D Gauge to which Stone is broken.	E Average Quantity per Day.	F Proportion of 1, Macadam; 2, Gravel; and 3, Waste.	G H.P. required.	H Cost per Ton.	I Duration of Jaws.	J Cost of Breaking same Stone by Hand.	K Value of Broken Stone at Depôt per Ton.	L How Machine is worked, Fixed or Portable.
Mountsorrel ..	20″×9″ and rolls.	Blake and Hambly.	$2\frac{1}{4}$″ & $1\frac{3}{4}$″	tons 60	1, 75%; 2, 10%; and 3, 15%.	20 I.H.P.	Not given	8 to 10 days.	2*s.* 4*d.* for $2\frac{1}{4}$, 2*s.* 10*d.* for $1\frac{3}{4}$.	6*s.* 6*d.* for $2\frac{1}{4}$ 7*s.* for $1\frac{3}{4}$.	Fixed in quarry.
Guernsey ..	..	..	$2\frac{1}{2}$″	..	..	..	..	..	2*s.* 6*d.*	..	..
Aberdeen ..	..	..	$2\frac{1}{2}$″	..	..	..	..	..	2*s.*	..	..
Sussex .. Flints	15″×7″	Blake's by Marsden	$2\frac{1}{2}$″ & $1\frac{1}{2}$″	60	1, 14 cwt. per ton.	6 N.H.P.	From 7*d.* to 10*d.*	Will break 500 tons.	Flints, 1*s.*	Flints, $2\frac{1}{2}$″ gauge, 7*s.*	Portable, and drawn by steam roller.
Sussex .. Purbeck stone	,,		,,	,,	2, $3\frac{1}{2}$ cwt. ,,	,,			Purbeck, 2*s.*	Granite, 15*s.*	
Sussex .. Boulders ..	,,		,,	,,	3, $2\frac{1}{2}$ cwt. ,,	,,			Granite, 2*s.*	..	
Great Ayton Blue whinstone	,,	,,	$1\frac{1}{2}$″	20 to 25	1, 95%; 3, 5%	,,	1*s.* 6*d.*	Notgiven	2*s.*	$1\frac{1}{2}$″ gauge, 7*s.*	Portable.
Great Ayton ,, ,,	20″×9″ and 10″×7″	Bradley and Maderson	2″	60	Not given	12 N.H.P.	1*s.* 3*d.*	1500 to 2000 tons.	1*s.* 6*d.* to 2*s.*	5*s.* to 6*s.*	Fixed.
West Coast .. Trap rock, syenites ..	15″×9″	Blake's	$2\frac{1}{4}$″	40	,,	7 N.H.P.	1*s.* 4*d.*	6 months	1*s.* 10*d.*	5*s.* 6*d.* to 9*s.*	In depôt.
West Coast .. Welsh granite	12″	,,	..	35	,,	..	1*s.* 1*d.*	Notgiven	2*s.* 6*d.*	11*s.* 6*d.*	,,
Warwickshire .. Rowley rag ..	15″×9″	,,	$2\frac{1}{2}$″	..	..	..	$10\frac{1}{2}$*d.*	..	2*s.* 3*d.*	7*s.*	,,
Somersetshire .. Carbonaceous limestone ..	20″×9″	,,	$2\frac{1}{4}$″	50 to 60	1, 70%; 2, 27%, and 3, 3%.	10 N.H.P.	6*d.*	5000 tons	1*s.*	3*s.* 9*d.*	In quarry.
Various Blast Furnaces .. Slag	15″×7″	,,	2″	20 to 25	..	6 N.H.P.	1*s.* 6*d.*	..	2*s.*	3*s.*	Portable.
Various Blast Furnaces .. ,, ...	21″×9″	Hall's	2″	70	1, 15%; 2, 10%	7 N.H.P.	1*s.* to 1*s.* 2*d.*	14 days	Not given	2*s.* to 2*s.* 6*d.*	In depôt.
Various Blast Furnaces .. ,, ...	15″×9″ and 16″×7″	Blake's and Hall's.*	2″	60	1, 15 cwt.; 2 & 3, 5 ,,	12 N.H.P.	3*d.*	12 months	1*s.* 3*d.*	1*s.* 6*d.* for Blake's, and 1*s.* 9*d.* for Hall's machine.	Fixed at slag heap.

Working together, as shown at Fig. 19.

DISCUSSION.

Mr. B. Hambly said he would make a few observations on the general principles of stone-breaking by machinery, of which he had had fourteen or fifteen years' experience. He would first of all say, most decidedly, that no one machine would be found to deal with all kinds of stone. His experience in Leicestershire was that, whilst rolls were eminently suited for the Bardon Hill stone, which was something approaching a slate, and which Messrs. Ellis and Everard were breaking, he was very doubtful whether *any* modification of Blake's breaker would suit that stone, which was however fairly well broken by rolls. Also the various kinds of trap or so-called granite found in South Leicestershire were not likely to be broken well by Blake's breakers. These had been tried by one or two quarry owners, and the result was always a more or less wedge-shaped stone. At Mount Sorrel he had found that there was a tendency to the wedge shape in spite of all the jaws which had been tried, and a great many had been tried. Some improved Blake's breakers, modelled at the works, had been put up, which were doing as good work as they could be expected to do considering the tough material they had to deal with, and the cost of preparing it for the breakers; for, after all, he looked upon the production of good macadam more as a question of cost than anything else. The road metal produced at Mountsorrel came from the waste material of the sett-makers, and unfortunately they could not afford to put upon that waste material a sufficient amount of hand labour to get it into a suitable form either for Blake's breakers or for rolls. With more labour, a very different result would be produced; and he thought that instead of complaints that machine-broken stone was inferior to hand-broken stone, then it would be said that the machine-broken stone was very much better. But, unfortunately, so low was the price of road metal that they could neither afford to put sufficient hand labour upon it nor to present it to the machine in the best manner for breaking. In all the Leicestershire stone quarries, with the exception of Bardon Hill, the stone for macadam came almost entirely from the settmaker, and thus the stone was often in large, clumsy pieces, very difficult for a Blake's breaker to deal with; and, in addition to this, the stone was thrown into the breakers without regard to its line of cleavage, and consequently the strain most frequently came in the wrong place. If there could be an intelligent eye always directing each piece of stone

into the breaker exactly in the right way, there would be an infinitely better result; but that was practically very difficult, if not impossible, when dealing with many hundreds of tons a day. As it was, the stone was put into the machine just as it came to hand, and though a fairly good result ensued it was at an immense cost, owing to the enormous quantity of gravel and chips which was produced, and which had very little commercial value.

The figures which had been given by the author of the paper put him (Mr. Hambly) very much in mind of the figures which the late Mr. Marsden gave him 13 or 14 years ago when he came to Mountsorrel to sell his breakers. Mr. Marsden assured him that he would certainly be able to break Mountsorrel stone at a cost of threepence per ton, and he reiterated that very strongly, because he (Mr. Hambly) refused to accept his dictum. Any one who took all the costs into careful consideration would find that they were very heavy; and when the extra waste caused by machine breaking was taken into consideration the question assumed a phase very different to that which it presented to a casual observer. He had committed to paper some results derived from working on a large scale, and which were thoroughly reliable. At Mountsorrel it had been found that a combination of improved Blake's breakers with rolls answered very well. The stone was run through the Blake's breakers and then passed through riddles, which took out first all the gravel and chips, and then the $2\frac{1}{4}$-inch macadam. The residue, called rejections, which would not pass through the $2\frac{1}{4}$ mesh, was caught at the end of the riddle and passed through a pair of rolls. By that means they obtained, in addition to the usual $2\frac{1}{4}$ stone, a very valuable stone $1\frac{3}{4}$ inch in size, which was used very largely where the roads had been coated with granite for a great many years, or where the traffic was light.

The $2\frac{1}{4}$ size finished in Blake's breakers was by some surveyors scarcely thought to be equal to the old hand-broken granite of Leicestershire, being more deficient in cubical character. That, however, could not be said of the $1\frac{3}{4}$ size finished through rolls, for this, both in shape and endurance, was superior to anything that had yet been produced, whether by hand or machinery; though of course it was not adapted for very heavy traffic.

With reference to the cost of producing granite macadam by machinery, as compared with the cost by hand breaking, much misapprehension existed. Leaving out altogether the preliminary costs of drilling, blasting, getting, knocking up,

&c., &c., which were the same in both cases, and taking the stone lying outside the settmakers' huts as if it were a waste material, then the costs were as under:—

By Machine, Cost per Ton.

	s.	d.
Loading	0	7
Breaking	0	6
Stores	0	5
Repairs	0	1
Locomotives	0	4
Total ..	1	11

By Hand, Cost per Ton.

	s.	d.
Labour and tools	2	2
Loading up	0	2
Locomotives	0	2
Total ..	2	6

Here apparently there was a gain of 7*d.* per ton, but when to the cost by machinery was added interest on the large capital invested in engines and plant, and the necessary depreciation on such plant, then it would be seen that there was really a very small gain indeed by the use of machinery. These results were obtained by taking quantities of from 50,000 to 100,000 tons, for at Mountsorrel machinery had been employed for more than twelve years on a large scale.

The real advantage of machinery in breaking macadam was not its superior economy but the command it gave the quarry owner over the labour market, and the power it gave of producing large quantities in a short time, so as to meet a fluctuating demand. In all machines he had yet seen, the great drawback was the enormous weight of gravel and chips produced; and to show this he would give the results of an ordinary full week's work with four Blake's breakers and rolls combined. Through the breakers were passed 1580 tons rough stone, and through the rolls 580 tons; the latter consisting of 153 tons settmakers' spallings and 427 tons of rejections. The results were as under:—

Blake.

911 tons	= 58 per cent.	broken X, or $2\frac{1}{4}$ in.
85 „	= 5 „	chips.
278 „	= 17·5 „	gravel.
307 „	= 19·5 „	rejections.
1581		

Rolls.

372 tons	= 64 per cent.	broken XX, or $1\frac{3}{4}$ in.
88 „	= 15 „	chips and gravel.
120 „	= 21 „	rejections.
580		

Thus out of a total quantity of rough stone put through Blake's breaker and rolls, viz.: 1581 + 153 = 1734 tons, only 911 tons X + 372 XX = 1283 tons were obtained, or less than 74 per cent., leaving at the least 26 per cent. of a nearly waste material, which constituted the great objection to breaking by machinery, and which it should be the chief aim of machinists to obviate.

Of course in breaking by hand there was a small percentage of gravel produced, but that was probably very little more than a fourth of the quantity produced by machinery, and that difference became very serious when dealing with 80,000 tons a year of rough granite.

Mr. C. Horsley said he thought that stone-breakers had done a great deal towards displacing (in some districts) such hard material as Mountsorrel and other stone, and bringing a new competitor into the field in the shape of furnace slag. The heaps of slag which have been seen for years in different parts of the country, which had been perfectly useless, and caused an expense on account of the ground they occupied, might now (to a certain extent) be utilized. The manufacturers of iron in Derbyshire and other counties, as far south as Wellingborough, had stone-breaking machines for the purpose of breaking up the slag, and the material thus broken was put directly into the trucks, and sent off for the repair of country roads. It was not worth while to break the slag by hand, and, in fact, the process was a dangerous one on account of the glassy character of the material; but broken slag was coming very greatly into use. He should like to know the cost of breaking Clay Cross slag. He thought it was about 1*s.* or 1*s.* 3*d.* per ton, and he believed that iron manufacturers got about half-a-crown per ton for it, delivered into trucks.

Mr. W. Schönheyder said Mr. Hall's paper was very interesting in describing the various stages which the stone-breakers had passed through since they were first brought out in America. He thought the plan which Mr. Hall had advocated —that of first half breaking the stone and then breaking it fully afterwards—was a decided improvement. That method was first effected in the machine of Smith and Roberts, and the plan was further improved by Mr. Hall's invention of forming the jaws in two steps. The division of the machine into two was of great value. The machine had to make two or three hundred revolutions per minute, and any one who understood the working of reciprocating machinery knew the difficulty of working it. The plan which Mr. Hall had introduced to prevent vibration had been adopted in Fraser's saw frame, so that it could be worked at almost any speed without vibration. That method reduced the strains considerably, and saved engine power in that way. He did not quite understand the remarks of the author about the stone turning over as it passed from the upper to the lower part of the jaw. He could not see why the stone should move from one side to the other and turn over. He thought the same advantage would

be gained by having the jaw of different pitches. For breaking the stone into cubes, some kind of roller system, if properly arranged, would work better. That opinion seemed to be corroborated by Mr. Hambly who stated that they got better work with rollers than with machines of the other form. For instance, better work ought to be produced by a machine like Archer's, although there was a very great mechanical defect in that machine, inasmuch as there was continuous rotary motion, and whenever the jaws came against the roller for the purpose of breaking the stone, the roller continued to move, and there was a sliding motion upon the stone while it was under high pressure, and that sliding motion would throw a great strain upon the gearing. Mr. Hall had remarked that there was a great saving in his machine in its not having to lift a heavy body as in the Blake and Marsden machines. There was, however, in that case, no power lost in lifting a heavy body, for whatever power was expended in lifting was given back when the weight descended; and therefore he (Mr. Schönheyder) did not think that Mr. Hall's arrangement in that respect was better than that of Marsden. Mr. Hall's machine, however, was better, inasmuch as the strains were divided, and the reciprocating parts were thoroughly balanced.

Mr. J. Mowlem Burt said that Guernsey was one of the principal places from which stone was imported to London, and in that island there was not a single machine. He believed that he was speaking quite within the mark when he stated that 200,000 tons of stone were brought from Guernsey to London every year. There were two reasons why they did not use machines in Guernsey. The first was that they had profited by the experience of the Mountsorrel Company, with regard to which Mr. Hambly had stated quite enough to show that as far as cost was concerned there was no advantage in machine breaking when the waste was taken into account. If they used machines at Guernsey and produced such a large percentage of waste, the material so produced would be worthless to them. He thought that machine manufacturers did not give stone-breaking credit for the science which it required. Perhaps it might be thought that the word "science" was rather a curious term to apply to stone-breaking, but there was really a science in it. If they noticed a man breaking stone at the roadside, they would see that he would take a stone and turn it up in a peculiar way. An ordinary observer might not see the reason of this, but if a person would himself try to break stones he would soon see the reason. Mr. Hambly had said that if the stones could be put properly into the machine by hand labour, they could then be broken into a more cubical

or oblong shape, according to the nature of the stone. But to do that would increase the cost very much. He thought that the term which the inventors of stone-breaking machines had used up to the present time was a very unhappy one. They had called the machines "stone-crushers," and that term was their death blow. The machines did indeed crush the stone, and they not only crushed it and so produced a result which could be seen, but they injured the texture of the stone, and that was a result which they could not see. The stone became pulverized, and underwent far more injury than the eye could detect. If the machines could be made to act as crackers and to give the stone a blow in the way in which it would be struck by a hammer, they would attain the result which was wanted, but until they could give a cracking blow instead of crushing the stones, stone-breaking machines would not answer.

Mr. Hall, in replying to the discussion, said that no one had had more experience than Mr. Hambly with machines for preparing macadam, but that experience was confined to one particular system—Blake's original machine improved by Mr. Hambly. In the paper he (Mr. Hall) had endeavoured to represent not one, but a dozen systems with which he was intimately and personally acquainted, having designed and constructed various kinds, and by frequent intercourse with the proprietors he was able to look at the question in a broader light. He had brought into prominence all the machines which had attained any position, starting at the begining, and explaining the different improvements effected since, bringing the question down to the present time. Mr. Hambly had justly remarked that a machine might answer very well in one quarry and yet in another, not many miles away, the same machine might not suit.

As to Messrs. Ellis and Everard's machinery, he had given prominence to it in the paper, but he did not think that any one would put down an elaborate system of machinery such as theirs in the present day, nor did he think that it would pay any person to do so unless he had an established trade consuming from 100,000 to 150,000 tons a year.

To break and rebreak the stone a great many times was undoubtedly the best thing that could be done. A man by the roadside did not hammer away at a stone always in the same direction, which, as had been explained in the paper, was the action of a Blake machine upon it; and so in Messrs. Ellis and Everard's machine the stone passed through perhaps a dozen operations, and the consequence was that there was less waste and a better shape of stone.

As to the question of cleavage already described by

Mr. Hambly, it was a notorious fact that whilst the stone was pitched into a machine regardless of its position or the side which would be most favourably acted upon by its action, the opposite course was followed by the hand breaker, who carefully studied its cleavage, and gave the blows accordingly. Now if anything approaching that selection was exercised in feeding a machine, a very superior result would follow.

Blake's machine would not always do in the South Leicestershire district for there were very marked differences in the Leicestershire granites, and while the machine would give a fair sample of road material in one place it would not do so in another. He believed that the Blake's machines as used by Mr. Hambly had been improved by him, and of course that improvement affected the result. According to Mr. Hambly's statement, the cost of breaking stone by machinery was 1*s.* 11*d.* a ton, and that of breaking by hand was from 2*s.* 2*d.* to 2*s.* 6*d.*; and as Mr. Hambly had waste material which could be utilized only by being broken for road material, he had to decide between those two figures. It appeared, according to Mr. Hambly's statement, that about 58 or 60 per cent. of the broken stone could be used for road metal, but he (Mr. Hall) had reliable information that the proportion was 75 per cent. of the same stone. He supposed that the remainder would be used as gravel for foot-paths or ballast, and if so, the price which it would fetch ought to be credited on the side of the machine.

Mr. Hambly said that he had taken account of the sale of the gravel.

Mr. Hall, continuing, said, that as to the question of rolls *versus* Blake's machine it must be borne in mind that before the stone was treated by the rolls it was put into the most favourable form by the first machine for the rolls to make the best of it. If rough stone was put into the rolls directly from the heap, it would be found that the rolls would make a bad sample of it, indeed very little good macadam would be produced, whilst the waste would be very greatly increased. The whole secret of a good sample being produced by rolls was that the stone was already sliced in one direction, and only wanted a final crack to be brought into the proper shape. In dealing with such stone as the Leicestershire granite, gearing was not the best mode of applying the power. Supposing that there were twenty teeth in the circumference of the roll, there would be twenty blows against the gearing, and hence the wear and tear of the rollers must be greater than that of a machine which dealt with the stone twice, as Smith and Roberts's did.

The question of the use of slag, to which Mr. Horsley had

alluded, was a very important one, and although slag could not profess to compete with Mountsorrel granite, it answered very well for country roads. The cost of breaking Clay Cross slag was, by hand, 1*s.* 3*d.*, and by machine, 3*d.* a ton. In the machine, which broke the stone by two separate operations, he had endeavoured to assimilate the action to that of hand breaking.

As to Archer's machine, that certainly produced a very decent sample, but it was at the expense of gearing and wear and tear. Intermittent motions had been tried without success. He did not quite understand Mr. Schönheyder's remark about the lifting of a heavy weight not consuming power. In the instance to which reference had been made, the power which was required to lift the weight was not given out usefully, and therefore the power was not recovered. In some instances, of course, as in the fly-wheel of an engine, the power expended in moving a heavy weight was got back. In the case of the stone-breaking machine, which was in question, the weight was lifted against the work which was being performed.

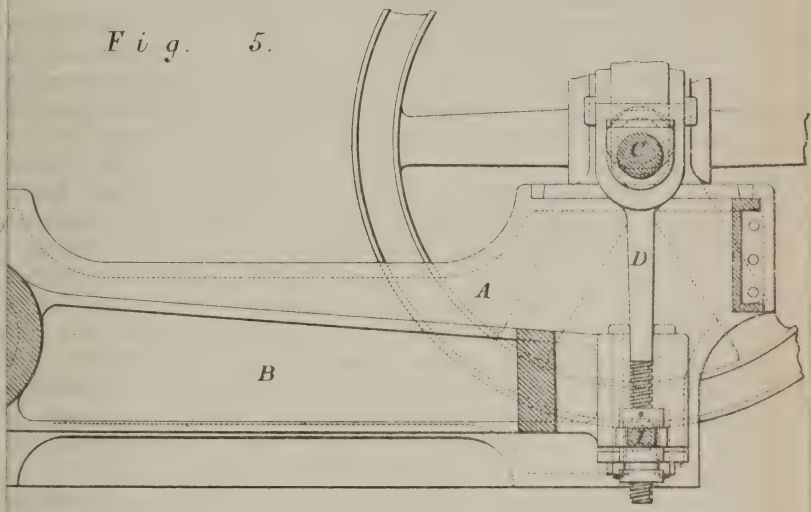
Mr. Schönheyder said, that the crank performed the work of lifting the weight, and when the weight descended it gave back to the crank all the work which had been expended in lifting it, minus friction.

Mr. Hall, in continuation, stated, that practical tests had shown that a machine divided in the way which he had described would do more work, with considerably less power, than a machine constructed similarly to a Blake machine, and the difference could not have been all due to reduced vibration. With regard to Mr. Burt's remarks, there might be local reasons for the machines not being adopted in Guernsey, and the question of the difficulty and expense of obtaining manual labour at once suggested itself. Possibly in Guernsey there was but one means of employing the labour besides agriculture, and this was in the quarries; the most enthusiastic admirer of machinery would scarcely prefer road metal so produced as against hand broken, and therefore it was essential for its adoption that the labour should be moderately paid, as in England. If labour were universally cheap, there would be an end to machinery; as the first incentive to introduce it would be removed. It appeared that there was no market for the chips and waste, but he (Mr. Hall) should have thought that there would have been a large sale for such material for asphalting, and for foot-paths and garden walks. As to the machines being called "stone-crushers," that was a wrong term. He was always careful to call the machine a "stone-breaker," and not a "stone-crusher." With regard to the machine injuring the

stone, he had raised that point in the paper, and he had endeavoured to get the opinions of users of stone-breaking machinery. The letters which he had received were contradictory in that respect, and he could not decide the question.

The PRESIDENT said that, with regard to the last observation of Mr. Hall, it appeared to him (the President) that Mr. Burt had not found fault with the term "stone-crusher," but that he had complained that the stone-breaking machine was really a stone-crusher, and that it did not perform the part of a breaker or hammer. Both Mr. Burt and Mr. Hambly had given the results of their large experience, and he (the President) gathered from both of them that it was questionable whether stone-crushing by machinery was, on the whole, an advantageous process. Of course it was against the grain for engineers to admit that a mechanical operation could be performed better by hand than by machinery; but they must always be prepared to bow to the logic of facts. With regard to Guernsey granite, the fact seemed to be that if the stone was broken or crushed by machinery there would be a large percentage of loss by waste, and that the waste material would have to remain at Guernsey instead of being turned to commercial advantage, for the want of a market for such residuum, and that therefore the breaking of stone by machinery was not admissible in the conduct of the business of Mr. Burt's firm. It seemed that the case was almost the same with regard to Mr. Hambly in Leicestershire, and that the extra loss occasioned was so prodigious as to take away all the advantage of using machinery. That being so, it appeared to him (the President) that there was nothing to hope for unless the machinery could be much improved, and a cracking or splitting effect be produced instead of a crushing one. But there might be some places where, notwithstanding the crushing defect, as it might be called, machinery was economical. For instance, stone which had performed its first purpose in the streets of our towns, might be dealt with conveniently by machinery. He had seen such machinery in the stone yards of some of our provincial towns, and he had been informed by surveyors that it was a very great convenience and advantage. But they must not shut their eyes to the fact that labour was not worth so much at the present time as it was when Mr. Hall's results were tabulated, and he could not help saying as he felt, that it would be a mournful day for England if labour should continue to be depressed in value till it could be employed in stone-breaking more economically than machinery.

Fig. 5.



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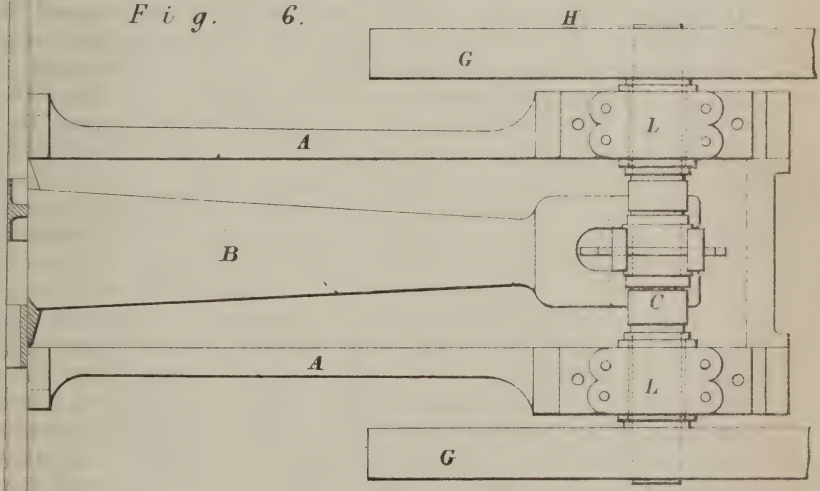

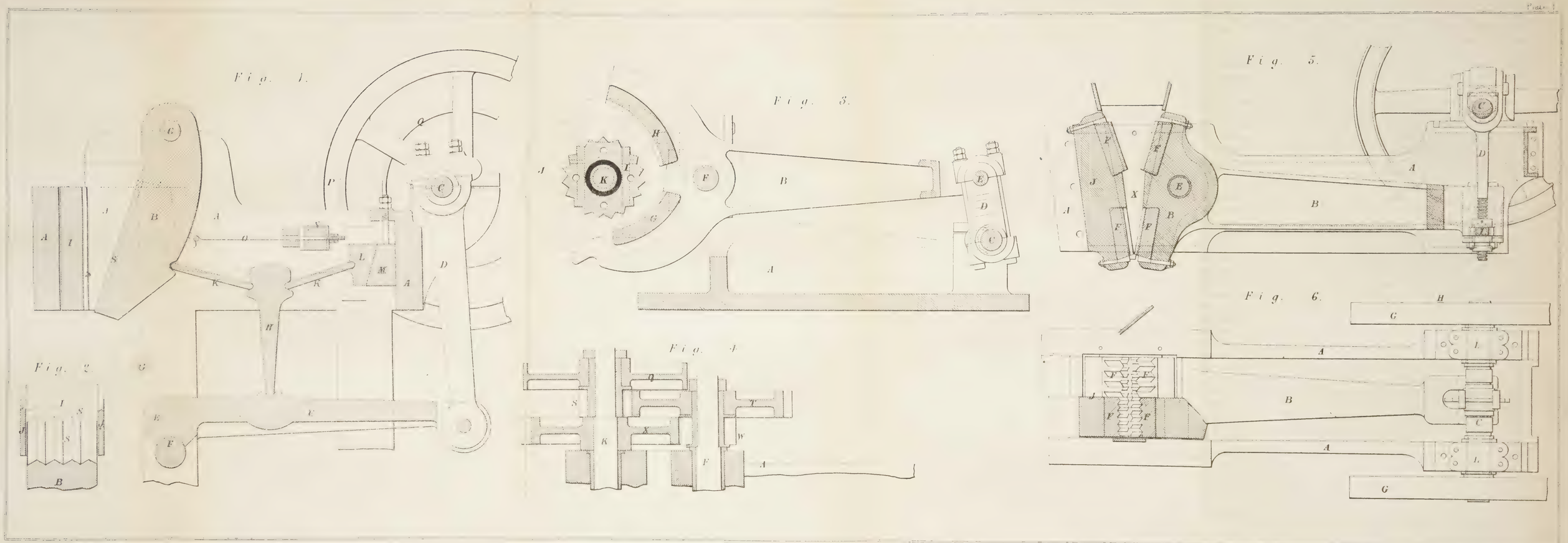

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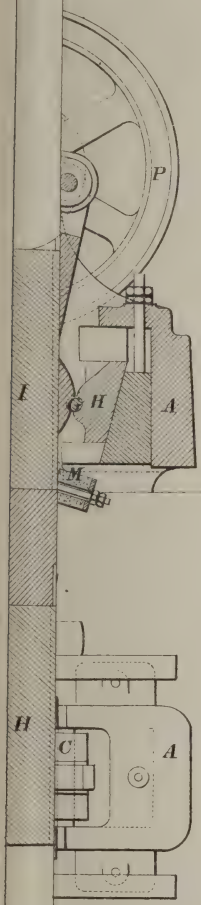

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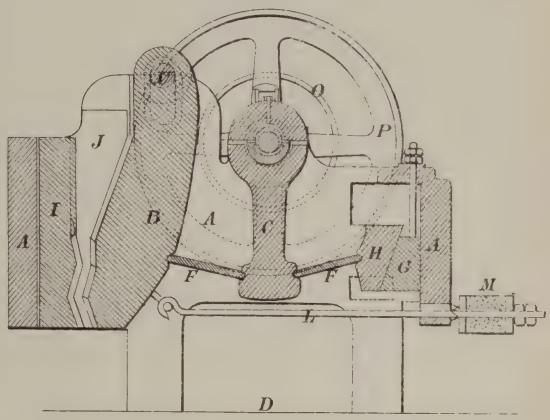


Fig. 13.

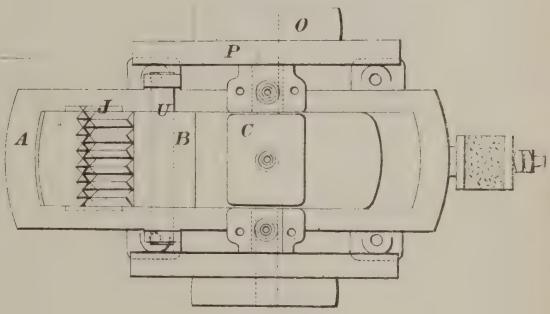


Fig. 14.

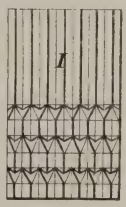


Fig. 7.

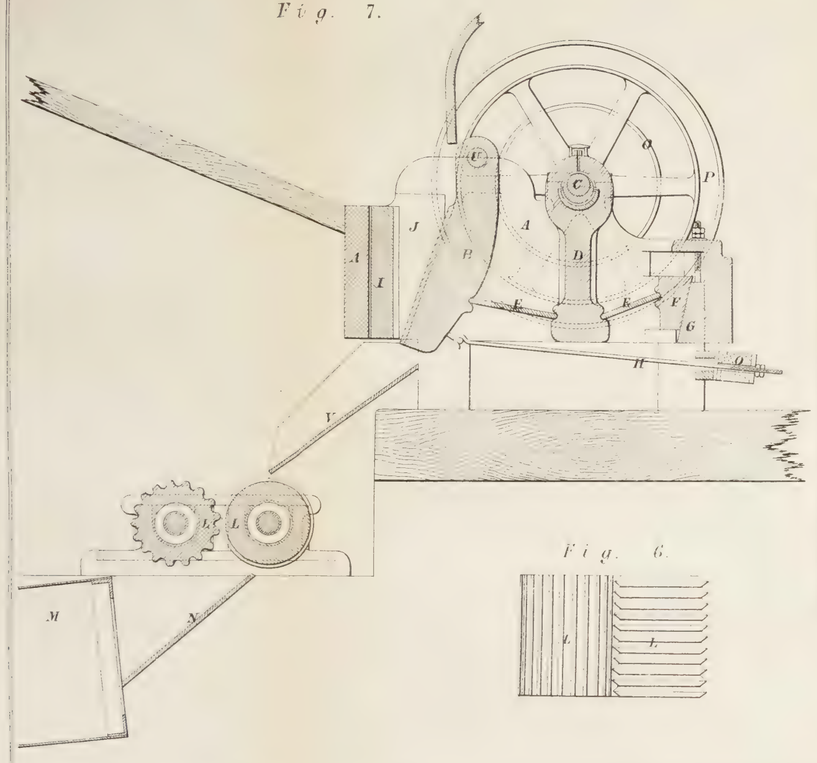


Fig. 6.

Fig. 5.

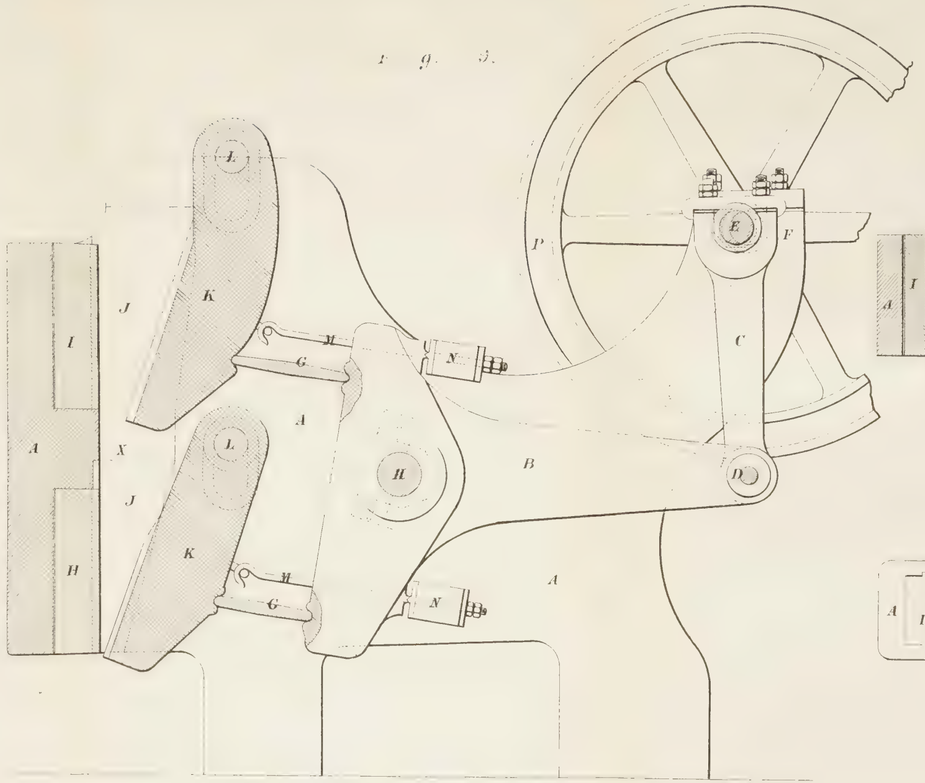


Fig. 10.

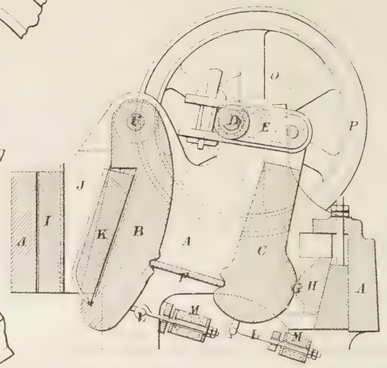
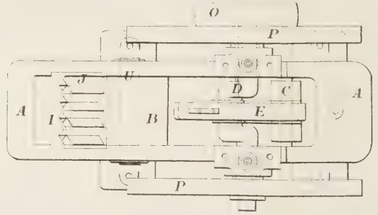


Fig. 11.



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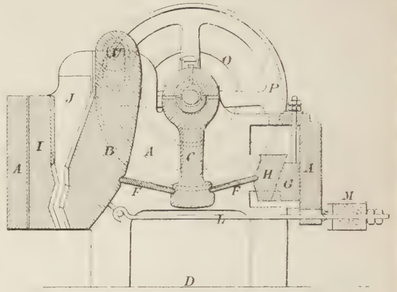


Fig. 13.

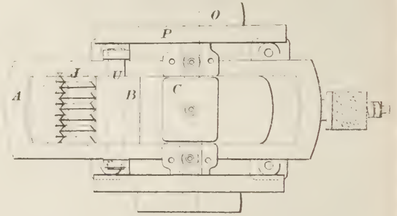
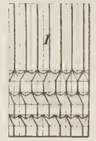


Fig. 14.



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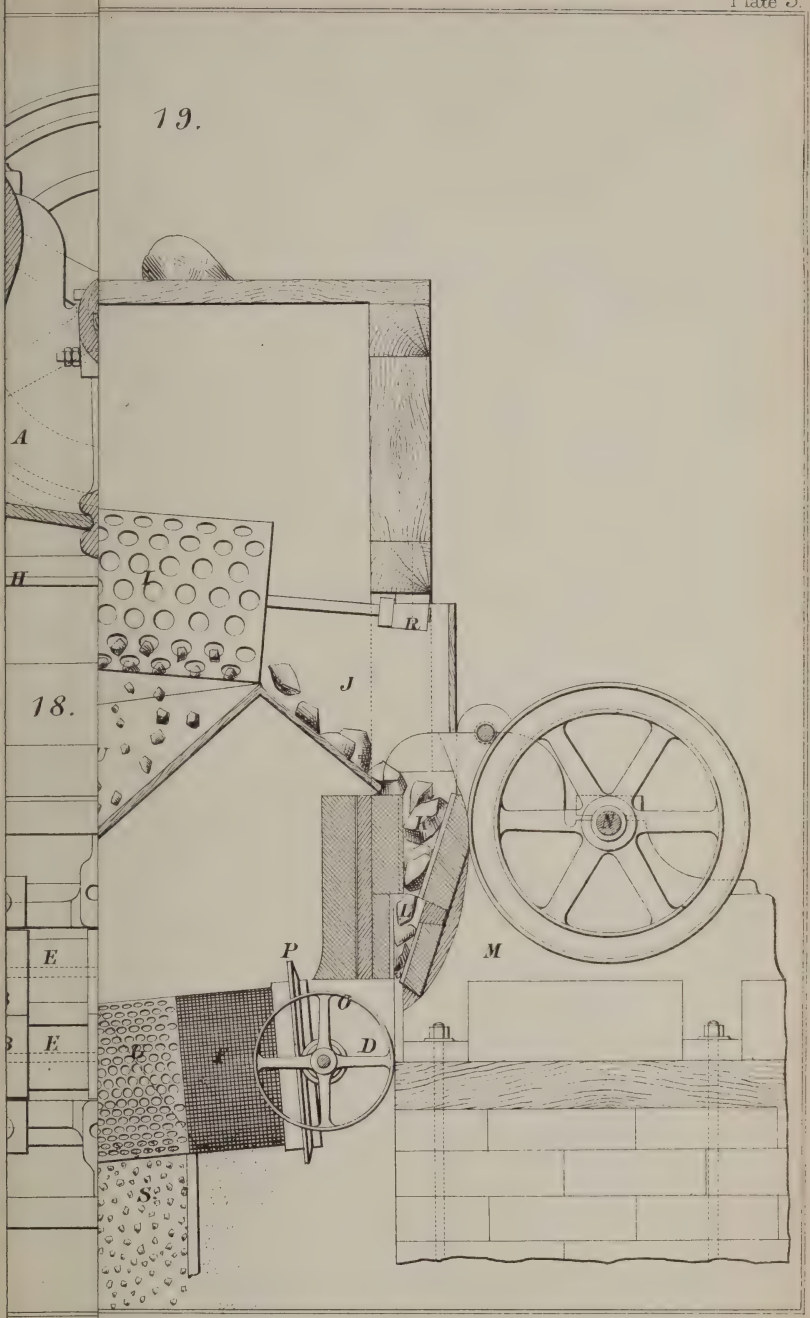
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Fig. 15.

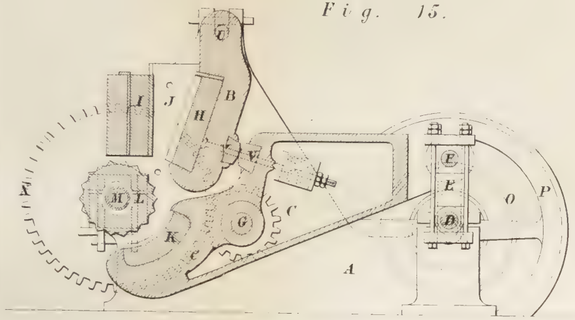


Fig. 17.

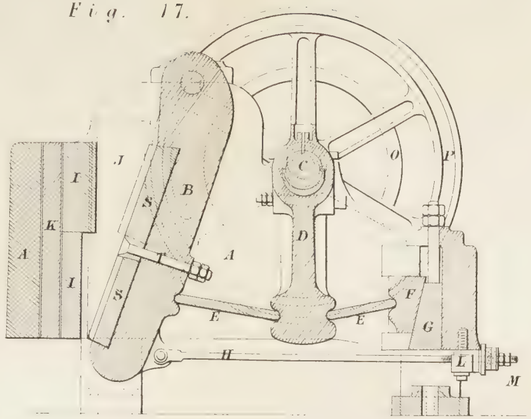


Fig. 16.

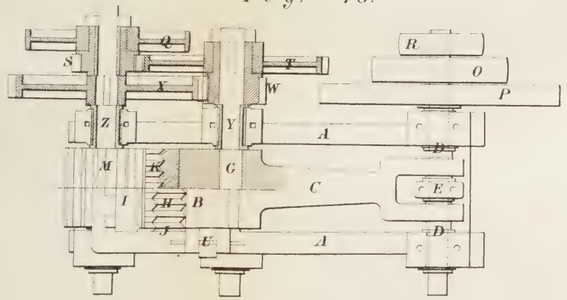


Fig. 18.

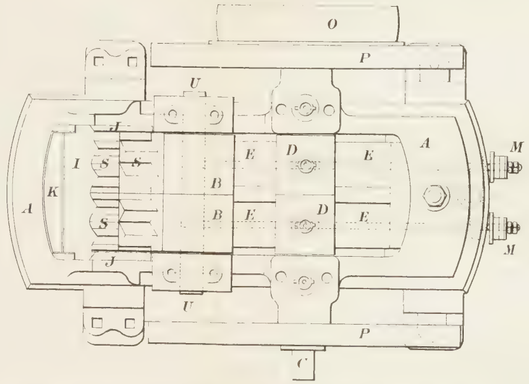
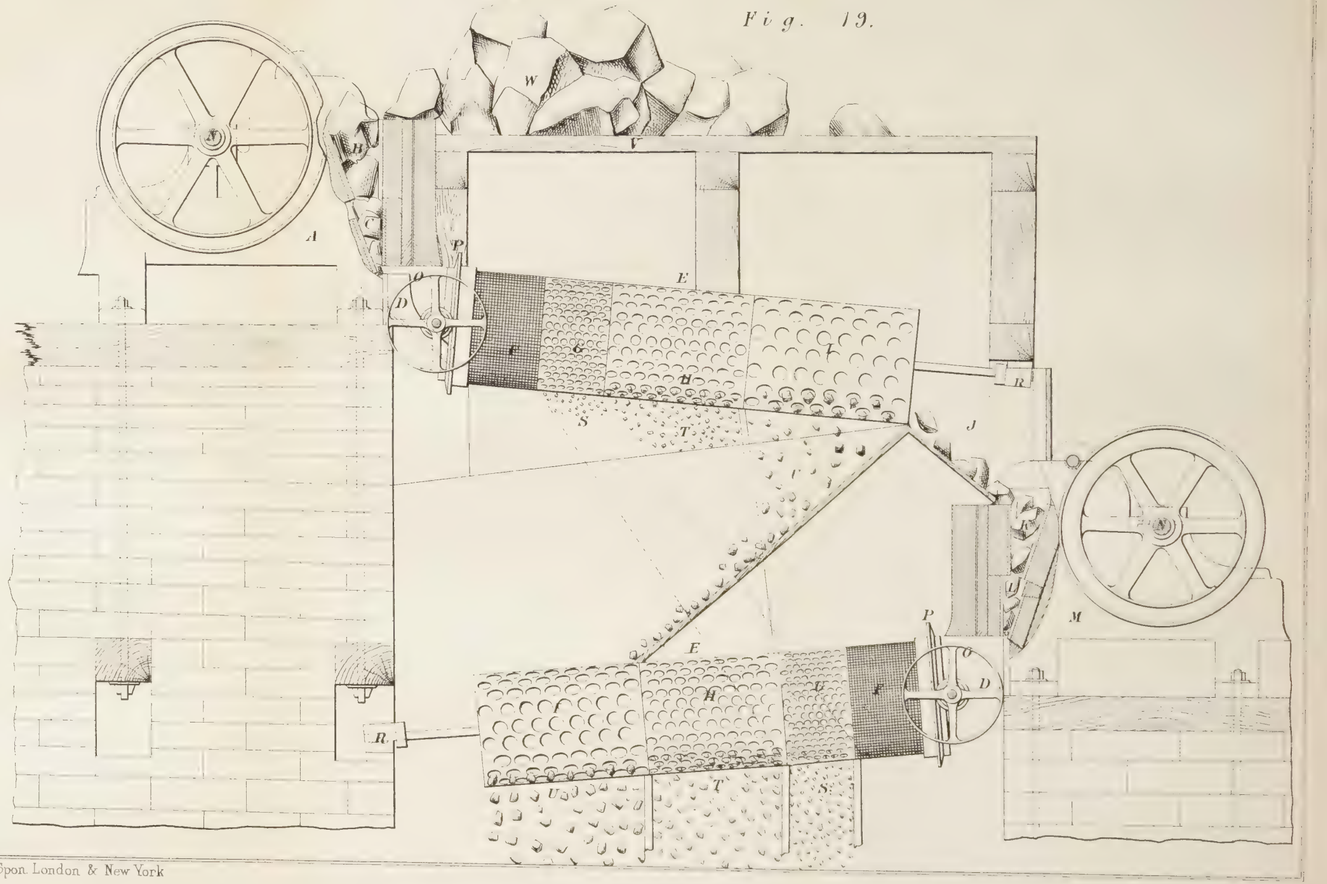


Fig. 19.



E. & F. N. Spon London & New York

May 5th, 1879.

ROBERT PAULSON SPICE, PRESIDENT, IN THE CHAIR.

HYDRAULIC CONTINUOUS AND AUTOMATIC BRAKES.

By EDWARD D. BARKER.

Railway brakes have been actuated by mechanical means, by steam, by compressed air, by vacuum, and by electricity. The author's system may be said to be the only one in which hydraulic power is used that has gone beyond the experimental stage. The reason for this it is rather difficult to find, as no one would question the applicability of hydraulic power as applied to a variety of purposes, such as lifts, hoists, compressing machines, dock gates, Armstrong's cranes, Tweddell's riveting machines, and for various other purposes, and in the work required to be done in the case of railway brakes, where a great force is brought to bear on the brake blocks throughout a train, there is a very strong analogy. Supposing there be not any insuperable objection to the use of water, it would appear to be what every engineer would naturally select for such a purpose. The author will therefore first point out the suitability of water for railway brakes, and he hopes to show that water offers advantages possessed by no other medium. He will afterwards explain the mechanical arrangements which he has designed to enable hydraulic power to be employed to actuate railway brakes.

Fluid brakes depend for their efficiency upon being kept tight. Water swells leather, and working surfaces are kept tight under the highest pressures. Hydraulic joints are most easily made, and leaks can be at once detected. Who has not experienced the difficulty of tracing a leak in a suction pipe of a pump? It may be broadly stated that it is not so much the time required to stop a leak as it is that consumed in finding it out which is wasted. Hydraulic brakes give evidence when they are out of order automatically in a way that with other fluid brakes is impossible. Water enables the power to be applied direct, thus dispensing with levers and gearing. In the winter common salt not only keeps the water from freezing, but maintains the brakes in the same state of efficiency as in ordinary weather. Water being incompressible, and the pipes and cylinders always being charged, the pressure required to be exerted on the brake

blocks can be applied instantaneously. Though it can be applied so quickly, the hydraulic power gives a powerful grip rather than a blow. The value of this as regards wear and tear will be obvious when it is borne in mind that the brake blocks have to move from $\frac{1}{4}$ to $\frac{3}{8}$ inch before coming in contact with the wheels, and when an elastic fluid is employed and the power is required to be practically instantaneous the blow will be very severe.

On the introduction of hydraulic brakes on the Great Eastern Railway in 1870 the author wished to give the drivers the control of the brake, but at that time custom had placed this power in the guard's hands and it was made a *sine quâ non* that the brakes must be arranged to work from the guard's van. In order therefore to obtain the results required, a weight of 12 tons was necessary to load an accumulator. A dead weight being inadmissible, the author was obliged to use springs; and although the results obtained were all that could be desired, appearances told against the arrangement. This system at that period was in direct competition with the chain brake, where all the tackle was distributed under the several carriages without necessitating any great amount of tackle in the guard's van. This caused an unfavourable impression with regard to the hydraulic brake. The amount of tackle necessary to work a train of twelve carriages with the chain brake, however, was far in excess of that required for the hydraulic. In order to demonstrate this it will only be necessary to compare the weights and number of parts of the two brakes. The parts and weights were accurately taken in 1874 on the Great Eastern Railway, and the figures are as follows :—Number of parts in a train of ten carriages and one van : chain, 2921 ; hydraulic, 1974 ; weight : chain, 121 cwt. 2 qr. 25 lb. ; hydraulic, 87 cwt. 1 qr. 2 lb.

The brake, as fitted to a number of trains on the Great Eastern Railway, consisted of spring accumulator, pump and friction wheel arrangement for working it, regulator, and tank. The author will only briefly describe the accumulator, pump, and friction wheel, as the other parts are common to his latest form of brake, and will be described further on. The accumulator was fixed in the guard's van, and was used for storing up water under pressure, so that, on opening a regulator or cock, the brakes might be actuated. The accumulator consisted of an 11-inch cylinder with an 18-inch stroke, containing a piston and rod. On the top of the piston-rod was a fork carrying a beam, and at each end of the beam were arranged a series of springs, ninety-six in number, which gave out a resistance equal to 12 tons. In order to charge this accumulator, and force the piston to the top of its stroke against the springs, a pump was used, which was worked by an excentric fixed

on one end of a shaft lying parallel with the axle of the van wheels. On the other end of the shaft a friction wheel, 2 feet in diameter, was keyed, and the periphery of this wheel was forced against the periphery of the van wheel by means of a spring, and was thus made to rotate. When the pump had filled the accumulator, the piston acted on a tappet, and opened a valve which raised the friction wheel out of contact with the van wheel, and thus stopped the pump. In this way the accumulator was automatically kept charged, and this arrangement is now used on the Great Eastern Railway. There are five trains thus fitted, and, according to the Board of Trade brake returns, they run no less than 173,000 miles every half year. This severe duty the brakes have been satisfactorily performing for the last six years.

The next development of the hydraulic brake was on the Midland Railway, when the control of the brake was placed where it should be—namely, in the driver's hands instead of in those of the guard. Before describing this arrangement, the author will briefly allude to a circumstance to which is partly, if not wholly, due the fact that at the present time so few trains are fitted with his brake. Owing to considerable difficulties experienced with donkey pumps, the author, by way of experiment, fitted up an arrangement of brakes in which the accumulator was charged without the aid of a force pump. The author had misgivings as to the results, and it inopportunely happened at the time this experiment was being made that the Newark brake trials were being instituted; and it was due to the failure of this experiment alone that such inferior results were then obtained. The author after this was permitted to apply a steam donkey pump of his own design to charge the accumulator, which has proved itself not only perfectly reliable, but has been working for upwards of three years without giving any trouble whatever. As this plan is identical with the latest form of the hydraulic brake, the automatic action being only an addition, the author will not occupy time needlessly in describing it, but will at once describe the outcome of all the preceding hydraulic brakes, viz. the hydraulic continuous and automatic brake, as fitted to an express train on the Great Eastern Railway, and which has been designed to meet all the Board of Trade requirements.

The author will describe, firstly, the hydraulic arrangement on the engine for supplying the necessary water under pressure for actuating the brake; and, secondly, the mode of applying the hydraulic power under each carriage so as to actuate the brakes, and the method by means of which each carriage carries its store or reservoir of water under pressure, so as to render the

brake automatic. The arrangement on the engine consists of four main parts, namely, an accumulator, a steam pump, a water tank, and a regulator. The accumulator—see Fig. 1—is conveniently placed under the foot-plate of the engine, and the steam pump is bolted to it. The tank is placed in the tender tank, and the regulating apparatus is attached to the engine, just to the right of the stopping and starting gear, and convenient to the driver. A small cock, for allowing the water to escape from the automatic pipes, is placed close by. The reason for having a special tank is, that salt water may be used in winter, which prevents the brakes becoming inoperative by reason of fresh water freezing in the pipes. During eight winters—this last winter having been unusually severe—these brakes have been in constant daily use, and salt water has been found perfectly effectual. By means of its use the brakes work as efficiently during the severest cold as they do in ordinary weather, and not one instance has arisen in which common salt has failed to accomplish the end in view. From the half-yearly Board of Trade brake returns, it appears that the hydraulic system is the only one unaffected by severe cold.

The accumulator consists of two horizontal cylinders of different diameters connected end to end and opening into each other. The larger cylinder, which is 15 inches in diameter, is for steam, and the smaller one, which is 10 inches in diameter, is for water, the stroke being 17 inches. Each cylinder has a piston, the two being on the same rod, and therefore moving together. The steam cylinder is placed in direct connection with the boiler of the locomotive by a steam pipe, so that the water in the smaller cylinder is always under pressure. The function of the accumulator is to mantain a supply of water under pressure for transmission of power to the brake blocks and to charge the automatic accumulator fixed under each carriage. The steam pump is fixed to the accumulator, and its office is to fill that receptacle with water against the boiler pressure on the steam piston, the steam piston answering the purpose of the springs in the accumulator previously described. The steam piston of the accumulator is a little more than twice the area of the water piston, the area of the steam piston of the donkey pump being three times the area of its water piston. Hence the pumping power is greatly in excess of the resisting power of the steam piston of the accumulator, thus always ensuring the proper charging of the accumulator with water under pressure, which is thus returned to it after it has done its work in putting on the brakes and charging the automatic accumulators. To the accumulator piston is fitted a rod, the object of which is to work a small piston in a cylinder, which is always full

of water. The water from the cylinder is conveyed to a gauge glass, close to the regulator on the foot-plate of the engine, and as the piston moves, the water in the gauge glass rises and falls, and thus indicates whether the accumulator is full or empty. The regulator and cock for letting water out of the automatic pipes is the main agent in the driver's hands for putting on and taking off the brake power. There are two distinct sets of pipes and two different ways of applying the brakes. One way is by admitting water under pressure to one set of pipes, which may be called the direct method; the other is by letting water escape from the other set of pipes, called automatic pipes. In the one case the source of power actuating the brakes is water under pressure stored up in the accumulator under the foot-plate of the engine. The other source of power is derived from small automatic accumulators under each carriage. By the direct method the water pressure in the brake cylinder can be regulated at will by the driver. In the case of the automatic arrangement the full power of the brake can only be applied in two ways by the guard or driver allowing the water in the automatic pipes to escape by opening a cock, or by the parting of the train and the consequent rupture of the pipes.

In working the hydraulic brake, the tank fixed inside the tender tank, and which holds about sixty gallons, is filled with water, steam is turned on to the accumulator, and from the accumulator is taken by a pipe to the donkey pump, which immediately starts and keeps on forcing water into the accumulator till the steam piston head comes against the pipe through which the donkey pump derives its steam. The steam is thus automatically cut off, and thus the accumulator is automatically kept charged. As soon as the necessity for making a stop arises, either the regulator or the automatic cock is opened. If the stop is made by the regulator—shown in Fig. 2—the way the power is regulated is thus:—The driver pulls forward the handle of the regulator, which is so arranged as to bring increased weight to bear on two levers, which actuate two valves; one valve admits the water under pressure, and is so arranged as to perform the office of a reducing valve, so that the pressure of water admitted to the brakes can be regulated. The second is a relief valve, and is similar to a safety valve, so that as the load on the lever in connection with this valve is increased or diminished, so that pressure on the brakes can be increased, and if in excess of the load the water escapes, and when the pressure is removed from the valve altogether the water escapes and the brakes are released. The reducing valve—Fig. 2—consists of a partly balanced valve, balanced by a small piston. Another piston on the same

spindle is employed to regulate the force of water admitted, and it acts thus:—The pressure in the brake pipes tends to close the valve which admits the water, and as increased force of water is required in the brake pipes so increased weight is required to be brought to bear on the spindle of the valve to overcome the force on this small piston and to allow water to enter. The other valve is a simple valve, and acts similarly to a safety valve.

The author will next describe the arrangement under the carriages and his automatic arrangement. As stated previously, there are two distinct lines of pipes. The mode of applying the hydraulic power to act on the brake block will be seen by Fig. 3. Water under pressure is conveyed to the hydraulic cylinder, and by it the piston is forced out, bringing the pressure to act on one brake block, while the cylinder is connected by rods to the brake blocks on the other side of the wheel, and by a retrograde movement the blocks are drawn on to the wheels, which are then gripped between two blocks. The automatic accumulator through which the water has to pass, whether the brakes are applied on the direct system or on the automatic plan, is an auxiliary apparatus, and it consists of two cylinders—a large and a small one—and their attachments, which are placed under each carriage—see Fig. 4. The water under pressure is conducted from the accumulator under the engine by a distinct set of pipes, called the automatic pipes, to these cylinders. The larger of the cylinders is furnished with a back stop valve, so that water is prevented escaping from it. The pressure of water in the automatic pipes leading to the accumulator is exerted against a ram in each accumulator, which is pressed from the other side by a powerful spring —see Fig. 4—against the water, the superior pressure of which keeps the springs compressed. As the ram in the small accumulator is forced back by the water it actuates a valve, which prevents the escape of the contained water so long as there is any pressure of water in the pipes. Should, however, the pipes be broken, as by the accidental parting of the train, the water escapes through the fracture, the spring forces the ram forward, opens the valve, and effects communication between the larger accumulator and the brake cylinder. The brakes are thus applied automatically by the power of the water contained under pressure in these subsidiary accumulators. At the same time, it is so arranged that the valve closes the communication between the main pipes used in connection with the ordinary brake apparatus and the brake cylinder. So long, however, as the automatic pipes are charged with water under pressure, and the small ram is in its normal condition—that is, forced back

against the power of the spring—the valve which it actuates uncovers a communication between the other ordinary brake pipes and the valve chamber leading to the brake cylinders, and thus, when the regulator on the engine is opened, and water under pressure is admitted to these pipes, it at once passes to the brake cylinder, and actuates the brake on the direct plan, and the power with which the brakes are ordinarily applied can be regulated with the greatest nicety; a peculiar and important feature of the hydraulic brake is thus retained.

The automatic pipes consist of two lines of small $\frac{3}{8}$-inch pipes. Thus it matters not which side of the train is next the platform, as either can be readily coupled up or uncoupled, besides which, by this arrangement there is always a spare line of pipes should an accident occur to either. The connection is formed by means of a small hose, which is permanently attached to the end of the pipe of one carriage, and its outer end is provided with a special form of coupling, shown at Fig. 5. At its outer end, or mouth, it has a plug cock, which closes as it is uncoupled. On the end of the pipe, in a corresponding position on the other carriage, is a cock, so constructed that when the hose pipe is fitted close into it one-quarter turn of a lever not only makes a water-tight coupling, but actuates a plug on the cock and that in the mouth of the hose, and thus opens communication between the two carriages. Separate cocks are thus dispensed with, and the risk of their being turned on and off inopportunely is avoided, which is a point of the highest importance, and one upon which the effectiveness of the brake depends. The cocks cannot be accidentally opened when not required—that is, when the couplings are disconnected, which would let the water out, and put the brake on—as the lever of the cock is provided with a catch, which is released by the act of fitting the hose pipe up to the cock. The author employs a special form of coupling for coupling up the ordinary brake pipes, which is shown in Fig. 6. There is no risk of its becoming uncoupled; it is easily coupled, and makes a perfectly tight joint.

Where it is necessary to arrange the brake tackle in the guard's van so that the guard can apply the brake by hand, a special form of hydraulic brake column is employed, as shown at Fig. 7. The arrangement shown at Fig. 8 is a plan for enabling slip carriages provided with hydraulic brakes to be worked when slipped from and attached to a train and engine not so fitted. To operate the brakes of these carriages the guard presses a lever in his compartment, and this forces a friction wheel against a drum fixed on one of the axles of the carriages. The

train being in motion, the drum is thus made to revolve and to wind up a chain, which is carried over pulleys to a ram, which is forced into a cylinder full of water, as shown at Fig. 8. The ram being thus forced in drives the water under considerable pressure through the pipe to the brake cylinders, and the brakes are thus applied. The degree of pressure exerted by the brakes is governed by the force applied by the guard to the lever. Carriages so fitted are slipped from the continental express leaving London at night for Harwich.

Having described the arrangement for storing up hydraulic pressure and bringing it to bear most effectually on the brake blocks, the next consideration is the regulation of that pressure. Brakes are required for two purposes, namely, for security, so that on an emergency a train can be stopped in the shortest distance, and for traffic convenience, to enable time to be saved in stopping at stations. There is further a negative advantage attendant on their use, they not only save time in stopping at stations, but by furnishing trains with an effective means of stopping, it enables them to run between signals in bad, slippery weather at the same speed as in dry weather. The confusion that arises from delays at such seasons is thus avoided, and the source of danger arising from unpunctuality of trains is got rid of. With the block system of signalling unpunctuality ought not to be an element of danger. Still there are few railway men who would not admit that unpunctuality gives rise in certain cases to confusion, and confusion to risk. When used for emergency the brake power is required to be of such a character as to bring its force to bear in the shortest time and as simultaneously as possible throughout a train. For a certain class of accidents the application of the power should commence from the rear of the train, and if it cannot be thus applied the next best thing is to have the brakes applied as simultaneously as possible, so that there shall be no tendency to telescope the train but to create force sufficient to give the greatest retarding effect possible. When used for the second class of stop, the power is applied with the best advantage generally. A little power at first, gradually increased or diminished as found necessary, is best to pull the train up at the spot required, care being taken first to release the brake before it has come to a dead stop. In this way the passengers are unaware of the application of a brake on the train, as by releasing it at the last moment no jerk is experienced on the train coming to a stand. By applying increased force as the train moves slowly, time is saved, for it is when the momentum is destroyed, and the train speed reduced to ten and five miles an hour, that the time is lost, and seconds rapidly count up.

Brakes applied thus must bring considerably less strain on the brake tackle and rolling stock. It will thus be seen that there are two distinct classes of stops to be provided for. In order always to have in practice the maximum brake force at command for emergencies the water pressure in the train reservoirs should not be capable of variation when in action, the maximum force should be there independent of any attention on the part of the driver, otherwise in a case of emergency the pressure in the reservoirs may be considerably under what it should be, and the efficiency of the brake would be impaired and disaster would result. It will be evident that by means of the regulator described for ordinary stopping, the driver can increase or diminish the pressure at will, and in case of danger by pulling the handle over hard, he at once applies the pressure of water in the reservoir, which is always a little more than double that of the pressure in the boiler, and if the brake is at work he always has this maximum pressure at instant command, and thus any carelessness or oversight on his part at a moment of danger is not likely to deprive him of the full power the brake is capable of exerting.

The author now comes to a point to which he believes the Board of Trade rightly attach considerable importance, viz. the necessity of meeting the case of a carriage leaving the metals and of preventing the brakes aggravating instead of mitigating the disaster. Many cases have occurred when carriages have been off the road where the driver has had the presence of mind to bring his train gradually to a standstill, and the train has run a considerable distance, but eventually has been brought up without a serious disaster resulting. On the other hand, if the driver had suddenly reversed his engine and put the brake power on, the carriages would have telescoped instead of keeping the couplings in tension, the result being the couplings breaking and the carriages getting adrift. With nearly all the continuous brakes actuated from the engine, the power commences from the engine, and different degrees of time, measured in seconds and parts of a second, elapse before the power reaches the rear end of the train. In some systems this delay is worse than in others, and this must generally be admitted to be a defect, and as the author has stated, if the application of the power cannot be commenced from the rear it ought to be simultaneous throughout the train, and this latter condition is fulfilled by the hydraulic direct brake. In order to demonstrate this conclusively it would be necessary to fit each carriage with a pressure gauge, and by electrical means obtain the exact time the needle pointed to the maximum pressure. It will, however, be conceded that owing to the

incompressibility of water, whatever the pressure is at one place it must be everywhere else. On account, therefore, of water being inelastic, this simultaneous action will be obtained much more perfectly with it than with an elastic medium, and results in practice fully bear this out. Simultaneous action must not be judged from the time the blocks touch the wheels, but from the instant hydraulic pressure is brought to bear, and this the author considers will be found to take place at the end of the train at the same moment as on the first carriage, and practical experience confirms this, as, however rapidly the hydraulic brake is applied, the couplings remain in tension just as when the engine has steam on.

The author will now notice the objections which have been made to the use of hydraulic power. There is a strong notion that hydraulic brakes are useless in winter. The experience of seven winters, however, shows that common salt has been perfectly effectual in preventing freezing. The Board of Trade brake returns show that nearly all other systems of continuous brakes in ordinary use have been affected by the frost, whilst with the hydraulic brake not a single failure has arisen from this cause. Another objection is that a tank has to be provided. Now only sixty gallons of water have to be carried, and the same water is used over and over again. There can therefore be no practical objection to this. It has the advantage that it at once furnishes the driver with an unerring guide as to the fittings being tight. He will at once be aware of any loss of water, and it is certain that he will not cease reporting such leakage until it is put right, as until it is, he will have the trouble of filling his tank very frequently.

Another stated objection is that the hydraulic brakes are rough in their action. Now, of all the brakes in use there is not one which is so distinguished for being an easy riding brake as the hydraulic. Anyone who has been in the habit of riding in trains fitted with this brake can vouch for the fallacy of such an objection. The last objection to the hydraulic brake is its cost. The author will be glad to give the exact cost, but as he has only fitted up an experimental train on the Midland Railway, and another on the Great Eastern Railway, both differently arranged, the Midland being the first train fitted up from the engine, and the Great Eastern the first on the hydraulic automatic principle, he will not commit himself to figures. He may, however, state that he is prepared to fit up trains at a less cost than that of any other system giving similar results. He does not suppose that the fitting up of the tackle, both in the case of the Midland and Great Eastern Railway trains, was otherwise than costly, but the sums expended

were not only employed in attaching the works to the carriages, but in alterations by way of experiment and modification and improvements which experience showed were desirable.

The next point to be considered, and perhaps the most vital one, is whether hydraulic power is not only powerful but rapid in its action. To apply the brakes it is necessary, in the first place, to fill the pipes and cylinders and supply sufficient water to take up the slack of the brake blocks. The pipes and cylinders in a long train hold a considerable quantity of water, and if they had to be filled each time the work done would be very great. As, however, the pipes and cylinders are always charged, about two gallons of water is sufficient to set the brakes, the pipes being 1 inch in diameter and the pressure 350 lbs. to the square inch, a simple calculation will show how instantaneous must necessarily be the effect. This has reference to the direct brake.

The author will now consider the amount of water that has to escape to set the automatic brake. To do this there is a ram under each carriage 2 inches in diameter which has to move $\frac{1}{2}$ inch. It is loaded with a weight of 400 lb., and the smallest diameter the water has to pass through to escape is $\frac{3}{8}$ inch; a simple calculation will demonstrate that with a train of twelve carriages less than a second will suffice to get the brakes on. It will thus be apparent that with hydraulic power only sufficient fluid under pressure is required to take up the slack of the brake blocks, and with the automatic arrangement the amount of water required to escape to set the brakes is only the displacement of the small rams. With an elastic medium, however, the extra duty is involved of charging or permitting to escape the contents of the pipes or cylinders. The work to be done in the latter case is therefore necessarily greater than with water, and consequently in practice uncommonly good results ought to be obtained with hydraulic power, and the results of daily working fully bear this out.

It may be stated that in 1879 a trial of the hydraulic brake was conducted by the locomotive department of the Midland Railway, to ascertain what it would do at a speed over fifty miles per hour. The train consisted of ten vehicles, and was stopped in 200 yards. This result would certainly be improved upon with the train recently fitted and running on the Great Eastern Railway. Trials such as these are important and interesting, as showing under certain favourable conditions what are the shortest stops that can be made with different systems. The author believes, however, that locomotive engineers receive with considerable caution all such data. The question with them is, what can be accomplished in every-day

working by those men who have to use the brakes. An engine driver soon finds out what load his engine is equal to, and in the same way he soon finds out to what extent he can rely upon a given brake, and what it will do.

Lastly, as regards the effect of water on the parts of the apparatus. As the paper has already reached a considerable length, the author will only state briefly that water and leather have long been friends, and that indiarubber stands the action of water better than that of any other fluid, and the metallic parts not being exposed to the atmosphere, the oxidizing effects that would otherwise be injurious are not sensibly felt even when salt and water are employed, which the author feared at one time would be considerably more destructive than it has proved to be.

DISCUSSION.

Mr. J. Bernays said he must congratulate Mr. Barker on the great improvement that he had made since the former occasion on which his brake was described before the Society, especially in the accumulator. He believed that there was something said at the former discussion as to the very great complication of the accumulator. There were then some four or five springs used in order to keep up the pressure. Mr. Barker had now brought the brakes into action directly by means of steam, and there was the additional advantage that, whatever pressure was put on, it would keep on equally right through from one end to the other. No doubt it acted very satisfactorily on the brakes themselves. There were a few points in the paper which, perhaps, might raise some questions. One was as to the best fluid for use in brakes—whether liquid or gaseous. There were various points to be considered. Water was well known to be inelastic. Whatever movement the accumulator made must be transmitted directly through to all the brake blocks; but he could not quite agree with Mr. Barker's statement that the motion must be instantaneous throughout the whole train. He might be quite right in what he said as to the simultaneous start, before any movement had taken place in any of the pipes; but it must take some time for all the brakes to get into work, because the water had to fly from one end to the other, and to fill up the spaces left in the cylinders by the advancing plungers. There were a number of elastic pipes and there might possibly be some air spaces in them which required filling up. He should like a little more explanation about the automatic accumulator. Was pressure supposed to be put on when the train started?

Mr. Barker said that was so, and the water under pressure

which was always on acted also on a valve that released the brake.

Mr. Bernays said that another point was raised in the previous paper on hydraulic brakes, and that was with regard to the double brake blocks gripping the wheel on both sides. It appeared to him that if the brake blocks were hung from the framework of the carriage, so soon as the wheel was gripped on both sides, it would keep as in a vice, and, as it knocked the rail, the vibration must immediately be transmitted to the carriage-frame itself, and make very hard riding. He observed that there was now some alteration made in the blocks. They were hung loose on centres. Whether that would do away with the difficulty or not he should like Mr. Barker to tell them. He (Mr. Bernays) agreed that there was no difficulty in finding out a leak in the hydraulic brake under pressure, but a leak could be found out as easily in the air brake, for though it could not be seen in that case, air could be heard as it made its escape.

Mr. P. F. Nursey said he had had several opportunities of making trips with the hydraulic brake, both on the Midland Railway and on the Great Eastern Railway. He had recently had a run up from Ipswich on the engine with the hydraulic automatic brake, which was fitted on the Great Eastern express trains, and a very satisfactory run it was. They had an indicator fitted on the foot-plate, and according to it they neared one or two stations, within a comparatively few yards, at speeds varying from forty-five to fifty miles an hour, and they pulled up excellently well within the length of the platform. That was done on several occasions both with the automatic and with the ordinary continuous brake. There was no severe jolt given to the train—at any rate, as far as the foot-plate was concerned, and that was the place where it might be expected to be felt if it existed at all. The brake was put on and taken off carefully and with proper precaution, which showed that the man had perfect control over it, although at the time that he (Mr. Nursey) made the run, it had not long been in his charge. He made some inquiries of the officials, and there was an expression of great satisfaction both with the brake and with its working. As Mr. Barker had said, the brake had had a good test during the very severe frost of last winter, and—according to his (Mr. Nursey's) inquiries—there had been no hitch nor inconvenience of any sort caused by the frost. As far as its working was concerned, the results were so satisfactory to the officials that he (Mr. Nursey) wondered why the company did not adopt Mr. Barker's brake more generally.

Mr. D. H. O'Neale Neale considered that Mr. Barker

deserved great credit for the perseverance with which he had fought the battle of the brakes. If not the best brake, his was a very good one. One point in which it excelled all others was the very great ease with which the power was regulated by the driver. That was a point of some little difficulty in the vacuum brake, and of considerable difficulty in the Westinghouse brake. A great many cocks and other appliances had been invented by Mr. Westinghouse in order to overcome that difficulty, and it was not quite overcome yet. Another very strong point in Mr. Barker's brake was the great ease with which leakages were detected. It was very true that a leakage in an air brake made a noise, but an injector on any engine near would make a precisely similar noise, and it is then very difficult to detect the leakage without getting the finger right upon it. In the vacuum brake it was almost impossible to detect a leak, however experienced the engineer might be. One speaker had said that Mr. Barker's brake was likely to gag the vertical movement of the wheels; but he (Mr. Neale) thought that a hinged brake block did not impede the action of the springs; that could easily be demonstrated by a diagram. One advantage of that method of rigging was that there was no strain whatever on the journal. Those were very strong points. It was a very important thing to have a brake that would act upon slips, and Mr. Barker's brake acted very well indeed. Mr. Barker's brake had run 173,000 miles with only one failure. He (Mr. Neale) believed that that was higher than any other brake that was really continuous, and not merely sectional. A case had lately occurred where the brake had been applied by the driver but could not be released, as a porter had not coupled the pipes properly. With other brakes improper coupling resulted in failure, giving no previous warning to the driver.

Mr. Henry Robinson asked whether the use of salt had been found to act in any way unsatisfactorily on any of the parts of the brake. He had used hydraulic power for many purposes, and he could not conceive any medium so likely to be applicable to a brake as water. Although he had not had anything to do with brakes for railway purposes, he had applied hydraulic brakes to winding drums and similar purposes successfully. One speaker had mentioned that he thought that the water power would be less promptly applied to a brake than compressed air, on account of its taking a certain time to travel. He (Mr. Robinson) apprehended that the pipes were always charged and ready to be put into play at a moment's notice; and therefore one could transmit power by water more quickly than by air.

Mr. R. H. Tweddell said that he endorsed Mr. Robinson's remarks as to the suitability of water for the transmission of power in the present as in many other cases. In reference to the subject of the paper, he thought that the thanks of the railway public, and more especially of the travelling public, were due to Mr. Barker for his quiet and unostentatious efforts in connection with brakes. Several years ago Mr. Barker took him on the engine of a train fitted with one of his brakes, in daily use on the Midland Railway. Some of Mr. Barker's performances on that run perfectly astonished him, and some remarkable feats in stopping at short distances, were accomplished without any shock to the passengers. In one instance the engine passed one end of a station platform at the rate of about 50 miles an hour, but brought the train to a standstill before they reached the other end. He thought that few people considered the power required to stop a train. A train of fifteen carriages, travelling 60 miles an hour, and weighing, he supposed, about 200 tons, represented as nearly as possible, the energy exerted by a shot from an 80-ton gun. They might credit Mr. Barker with considerable boldness in attempting to annihilate such a force in so short a time. The only thing which he (Mr. Tweddell) considered to be in the slightest degree against the success of his brake was that there were so many little details to trust to in order to effect a stoppage, especially in regard to the automatic brake, but he did not pretend to have yet grasped the details of it. According to the drawings, it seemed to him that if there was one practically complete apparatus on every carriage, the train would be subject to a considerable number of chances of failure, and that it would be much better if Mr. Barker would bring water or a dead weight to bear, instead of so many treacherous springs. He thought that a dead weight would be preferable, but at the same time, he knew the difficulty of introducing dead weight under such circumstances, and therefore water under pressure seemed to be the best thing possible.

With reference to the instantaneous action of the brake, there could be very little question about it. The cylinders and valves and passages had not to be filled as was supposed by some speakers. They were already filled before the brake was put on, and he had no doubt that Mr. Barker's calculations were correct—that it could be put on in a second. It certainly seemed to excel every other brake as far as speed of application was concerned, for he had generally understood that it required two seconds for the best of the air and vacuum brakes. The difference between one second and two seconds did not seem much, but it meant, he believed, between 70 and 80 feet. A

speed of 80 feet a second equalled 54 miles an hour; and a great deal could happen while moving over 80 feet of ground. It was related of one of our most eminent engineers, that on one occasion a junior counsel who was examining him, ridiculing the idea of ten seconds making any appreciable difference, he simply took out his watch, and amidst perfect silence in court, looked at it for ten seconds; when the ten seconds had passed, his remark, "I think a good deal might have happened in that space of time," was hardly necessary to convince the Court, as anyone who cares to try the experiment will believe. As far as regarded the instantaneous application of the power, he thought Mr. Barker had chosen the right mode of transmission. In reference to the power which Mr. Barker put upon the brake, he should like to hear whether Mr. Barker's practice in this respect agreed with the power recommended by Captain Douglas Galton as being necessary for railway carriages. In conclusion, he should like to ask Mr. Barker whether he had had any trouble with his leathers in connection with the use of cast-iron cylinders. He (Mr. Tweddell) had had some little trouble with leather on cast iron. Guttapercha gave some little trouble, but rather less than leather, but he had lately come to the conclusion that there was nothing like leather after all, if the leather worked upon brass. The amount of friction that could be set up by hemp and other modes of packing was not generally sufficiently allowed for. In hydraulic work about docks, there had been hitherto an objection to the use of dock water where it was at all salt or brackish. He had never understood why it should be so, and he should be glad to hear if Mr. Barker found any difficulty when using salt. He was extremely glad to see that Mr. Barker was bringing his brake into more public notice, for if it was not so generally known as other brakes, it was to a great extent due to its never having been fairly tried in competition.

Mr. F. W. Hartley asked Mr. Barker whether he had got the brake so perfectly under his control that he could stop a train slowly by letting the wheels slip instead of binding them up suddenly. He would also ask whether Mr. Barker had ever tried glycerine instead of salt in the water that he used for his brakes.

Mr. Robinson said that the use of glycerine to prevent freezing was advocated a few years ago. As regarded salt water, it had always been held that there was an objection to use sea water or water from the docks. Possibly it might be because the water was so seldom changed there, and that foul matter was thrown overboard from steamers, and some chemical change might take place; and further, that the various chemicals in sea water might act differently to the pure. It would be very

interesting if Mr. Barker could say that he had found no ill-effect from salt water upon the leather. It had always been found that there was a difficulty in dealing with salt water, not merely with regard to leather, but also with regard to the metallic parts and the valve seats.

Mr. E. D. Barker, in replying upon the discussion, said that Mr. Bernays had made some remarks with regard to the simultaneous action of the brakes. In the paper he (Mr. Barker) laid considerable stress upon the hydraulic brake fulfilling that very condition. It was true that they had first of all to force enough water through the pipes to bring the brake blocks in contact with the wheels, but they had only to force two gallons through for that purpose, and there was a very high pressure to do that, and as soon as they got the hydraulic pressure to bear on the block in the front carriage, they had always got it on the blocks in the rear carriage. The blocks might not touch equally, but when they had got the effective hydraulic pressure to bear, the brake blocks were subjected to it equally, as stated previously, on the first carriage and on the rear carriage. When the brake was put on rapidly, it would be found that instead of the buffers going in slightly, the couplings remained in tension just the same as if the power was perfectly equal. Mr. Neale had combated some remarks that were made with regard to blows and shocks. If the members would look at the way in which the blocks were hung, it would be seen that as the carriage rose and fell the blocks, being fixed on a centre, would allow the springs to act and consequently permit the carriage to move up and down. And further the india-rubber tube allowed sufficient elasticity when the block was hung as shown to enable the springs to act on the carriage. Mr. Robinson and Mr. Tweddell had both drawn attention to the action of salt water on the working parts. Salt water was not found to be so injurious as it was expected it would be. He did not find any benefit from the salt water, and it certainly did not improve the leathers, but still it did not destroy them as much as was expected. Common refuse salt would soon eat the leathers away, but the best table salt would have very little action on the leathers. After a whole winter's use, he had found his leathers perfectly good. Of course, he had no cast iron in contact with them. As to the action of salt water on cast iron, he had found no injurious effect at all. That was a result for which he had been unprepared. After two years' working, he had not found the least corrosion inside the hydraulic brake cylinders. He attributed that to the fact that the iron was shut up, and was not exposed to the atmosphere, and that therefore no oxidizing effect could take place.

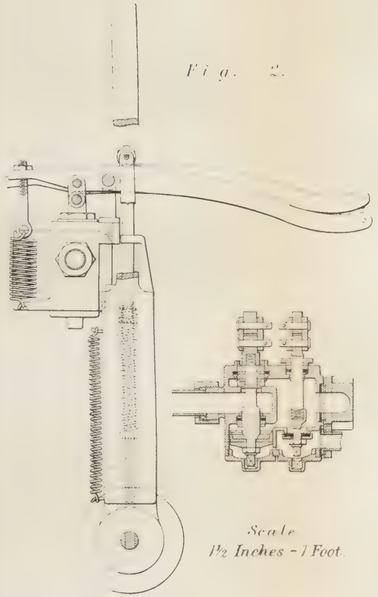
He had been asked whether it was not possible, in ordinary stopping, to apply a modified pressure, and not to grip the wheel so powerfully as to prevent it revolving. That was the very thing he had specially provided for, in ordinary stopping instead of applying the full pressure, he only applied just enough to retard the train. It was only in the case of an emergency that the driver applied sufficient power to stop the wheels. It was the very thing upon which he had laid so much stress, that he was able to adapt the retarding power to varying circumstances. With regard to the pressure on the brake blocks, the cylinders were each four inches in diameter; so that with 350 lbs. pressure they could generally get about 30 cwt. upon each brake cylinder piston. There were four blocks to each carriage, so that the brake gave more than the weight of the carriage when the full pressure was applied. He thanked the meeting for the very considerate way in which they had received his somewhat lengthy paper.

The President said that the paper and discussion had produced in his mind an impression decidedly favourable to Mr. Barker's invention. He (the President) had not had an opportunity of judging accurately with regard to the different systems of self-acting or automatic brakes generally beyond the observations which he had made as a constant traveller on railways. He had been very frequently impressed with the unsatisfactory character of those brakes, the power in which was applied too abruptly and too quickly. He had experienced a jerky action especially on the North London Railway. He did not know whose system was in use on that line, but he had felt the objectionable shocks as a traveller. Whether the jerk was caused by a too sudden application of the force, or was inherent in the system, he had no means of judging. According to his view of the subject generally the driver was the person who ought to have the chief control of the brake for use in an emergency, because he was the most likely person to see the danger. There could be no question as to the vast importance of having a power which might be applied discriminately and gently, according to the concluding words of Mr. Barker's paper, or with very great power to meet a sudden emergency. That was the object to be aimed at. As the discussion had proceeded, he had been deeply impressed in favour of the invention which Mr. Barker had described in his paper, and which had been ventilated that evening. He felt that they were all greatly indebted to Mr. Barker for his paper, and for the discussion to which it had led. Mr. Barker's invention seemed to be well worthy of general acceptance by Railway Companies.

Plate 1

REGULATOR.

Fig. 2.



Scale
1½ Inches = 1 Foot.

ACCUMULATOR AND PUMP.

Scale. ¾ Inch = 1 Foot.

Fig. 1.

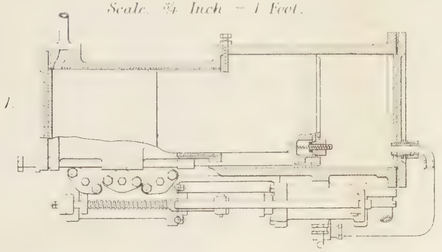
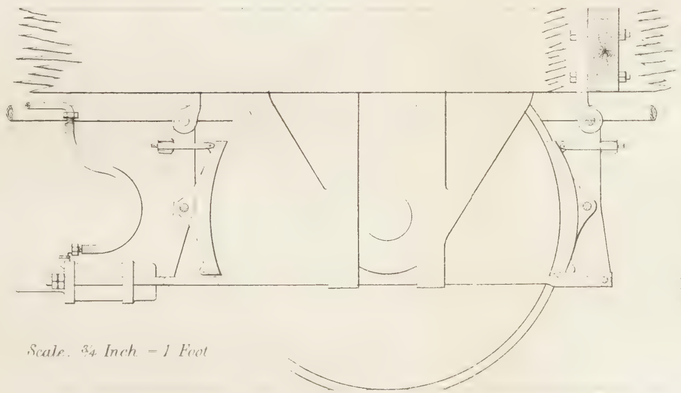


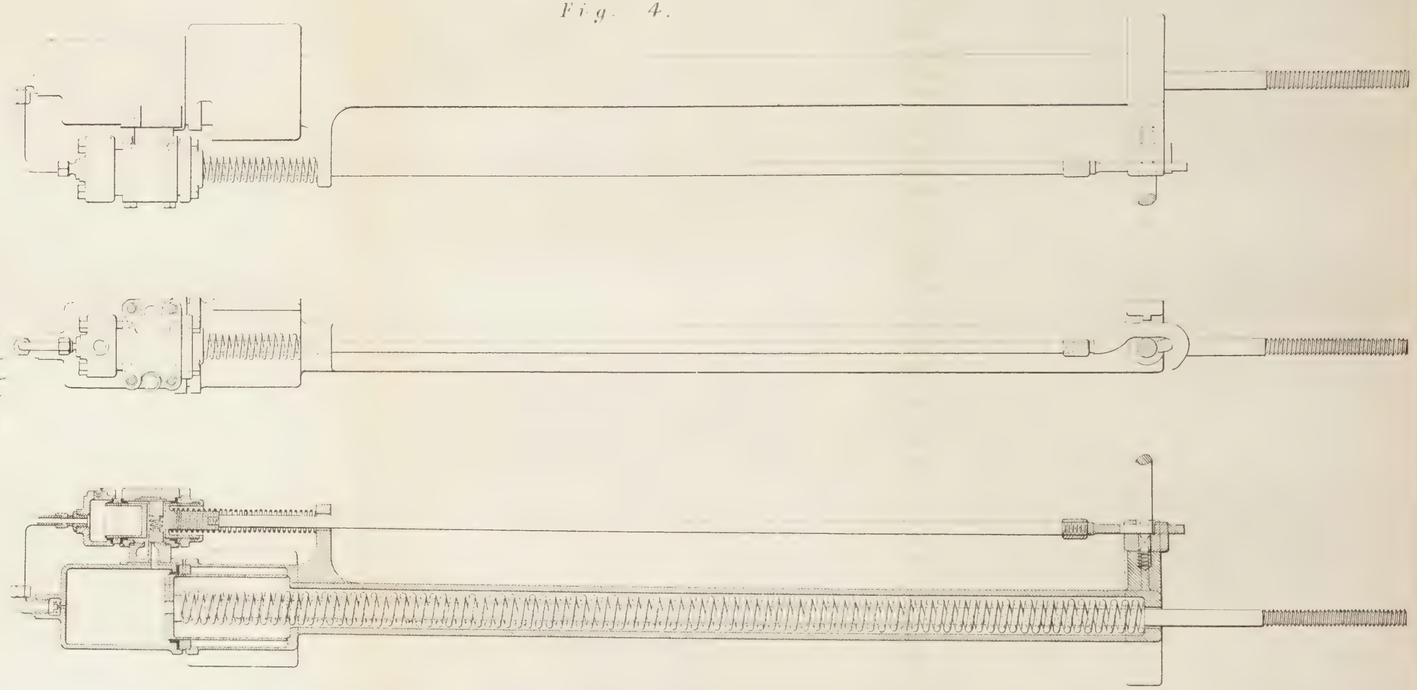
Fig. 3.



Scale. ¾ Inch = 1 Foot

AUTOMATIC AUXILIARY ACCUMULATOR.

Fig. 4.



Scale. 1½ Inches = 1 Foot

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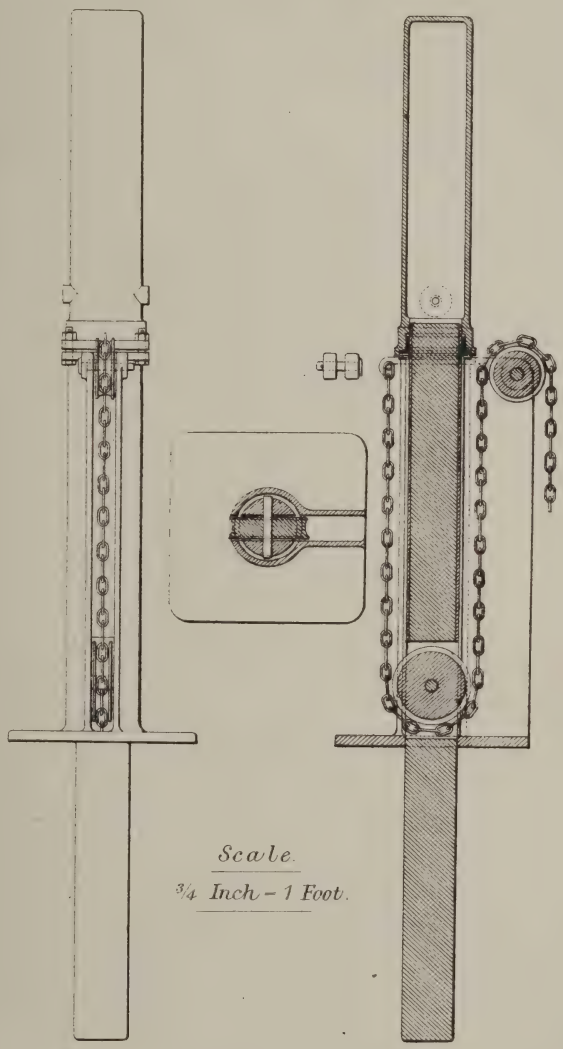
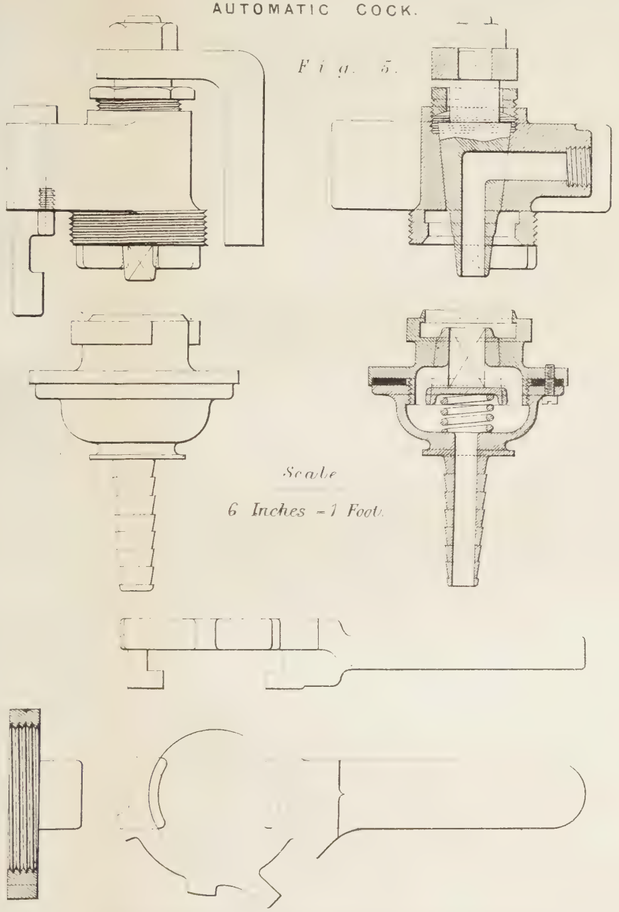
Fig. 8.



AUTOMATIC COCK.

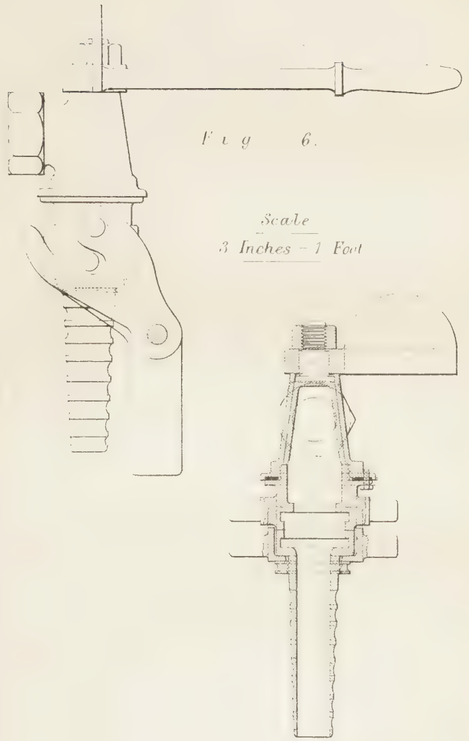
Fig. 5.



Scale
6 Inches = 1 Foot.

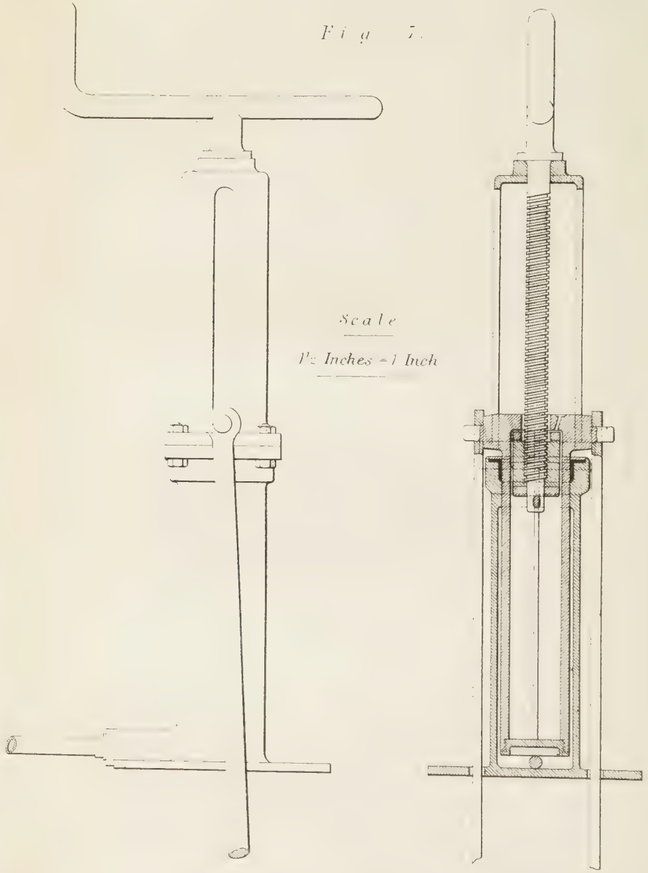
COUPLING & COCK.

Fig. 6.



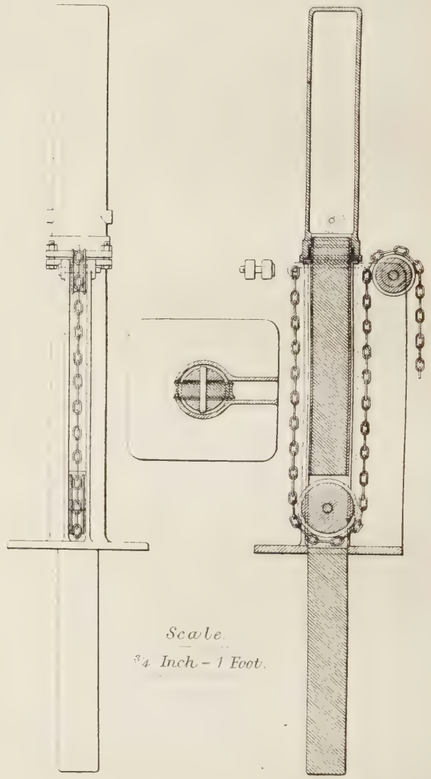
Scale
3 Inches = 1 Foot

Fig. 7.



Scale
1½ Inches = 1 Inch

Fig. 8.



Scale
¾ Inch = 1 Foot.

E. & F. Spon, London & New York.

June 9th, 1879.

ROBERT PAULSON SPICE, PRESIDENT, IN THE CHAIR.

THE MINERALOGY OF THE ISLAND OF SARDINIA.

By Mr. CHARLES J. ALFORD.

WELL known as the Island of Sardinia is by name, as the place from which cargoes of calamine and argentiferous galena are imported into the United Kingdom, there are but few persons perhaps who are personally acquainted with the interior of the island, and fewer still who have ever studied the geology and mineralogy of this most interesting country. The almost entire absence of roads among the lofty mountains of the interior, and the difficulty of intercourse with the natives in a country which has a distinct language of its own, differing greatly from any other in Europe, has completely shut out the ordinary traveller, whilst the great difficulty of working and transporting minerals when found, gives but little encouragement to the explorer. The author therefore hopes that the following experiences of several years spent by him in prospecting for minerals in the island will not be without interest to the Society.

Before proceeding to the more technical part of the subject, a few words on the laws in force in Sardinia relating to the acquisition and workings of mines may not be out of place, as a certain amount of knowledge on that subject is indispensably necessary to enable the explorer to deal with the inhabitants, and also with that very doubtful class of persons who are to be found almost everywhere, hawking mining properties for sale. The author has translated from the Italian the Mining Law now in force in those provinces of Italy, which constituted the old kingdom of Sardinia, and this translation is appended to this paper for reference. A few remarks in explanation will suffice here. In theory, the property of the owner of the land does not extend below the surface of the ground; and a mine is the property of the person who finds it. The practice is, that anyone discovering traces of mineral in any place takes out what is called a "permission of exploration," which is granted over an area of not more than four hundred hectares, and for two years.

Armed with this permission the explorer commences operations, and if he is successful in finding workable mineral, he calls upon the government engineer to declare the mine "opened" and then applies for a concession from the Minister of Public Works. The terms of the concession are fixed by the Government, and are generally a tax of from two to ten per cent. on the nett profits of the mine. On obtaining the concession the mine becomes the absolute property of the concessionnaire so long as he continues to work it according to law. A grave objection to which this system is open is, that as a permission of exploration is granted to any applicant, whether he be in a position to carry out any exploration or not, the whole country is permissioned to some one or other, and the *bonâ fide* explorer finds he has to purchase the permission or make terms with the holder of it before he can set to work.

The island of Sardinia, as will be seen by reference to the accompanying map, is divided by the various arms of a large alluvial valley, into four separate groups of mountains, in all of which metalliferous deposits have been found, indeed the whole island is covered with traces and indications of mineral. Unfortunately many of these indications, on being followed up, do not realize the anticipations of the explorer. The minerals which the author has found in the island are: galena, blende, calamine, copper pyrites, iron pyrites, magnetic and hematite iron ores, manganese, antimony, and coal. These minerals occur mostly in veins in the crystalline schists and in the granite, excepting the coal, or rather lignite, the occurrence of which will be hereinafter described.

The best known, and most important mining district in the island is that of Iglesias. Situated within easy reach of the sea, with the harbour of Carlo Forte on one side, and the railway to Cagliari for an outlet on the other side, it possesses far greater advantages as regards communication than any other part of the island, and has therefore in a corresponding degree been developed and worked. Here are situated the well-known mines of Monteponi, St. Giovanni, and Vieille Montagne, all producing galena and calamine, also the Duchessa mine, producing a very rich calamine in large quantities. To the north, on the junction between the schist and the granite, is the Monte Vecchio mine, with a splendid vein of very rich argentiferous galena. The same may be said of Monte Cerbu, on the south. To the west lies the coal basin of Gonessa, which will be described when the author considers the subject of coal. In the granite eruption on the shore of the bay of Cagliari are situated the large iron mines of St. Leone. Domus Novas

deserves a passing glance, the valley of Oridda being entered from thence, through a natural grotto or tunnel nearly a mile in length formed in a deposit of tuffaceous limestone of very peculiar formation. Mines around Domus Novas appear to have been worked at a very early period, as evidenced by the great heaps of scoria in the neighbourhood, much of which, has of late years been resmelted, yielding very valuable returns. The analysis of a specimen of this scoria is as follows:—

Lead	30·04
Iron	46·16
Sulphur	8·00
*Earthy matter, with traces of silver and zinc	15·80
	100·00

* Silver = 13 oz. per ton of lead.

It is a somewhat curious fact that in the tuffaceous limestone of the grotto strong traces of silver have been found, amounting in some cases to as much as ten ounces per ton of rock. Lead in the form of carbonate also occurs in the same rock, both metals apparently having been taken in solution by the waters of a river of the Silurian age and deposited with the tuffa in its formation. In the valley of Oridda, to which access is had by means of the road passing through the grotto, is situated the valuable calamine mine of La Duchessa, and the valley also abounds in the ruins of the small galleries and shafts of very ancient workings.

In the north-west corner of the island is situated the mining district known as "Argentiera," a small range of hills of Silurian formation in which veins containing rich argentiferous galena are worked. Situated on the sea-coast, these mines are easily worked, and the mineral easily exported; there are no special features in them to call for further observation.

Turning to the east, we find that nearly one-half of the island is occupied by lofty mountains, all of, more or less, metalliferous formation, and it is to this almost unexplored district that the author desires more especially to draw attention. On the extreme north lies a large tract of granite, culminating in the peak of Limbara, 4500 feet in height. This granite is traversed by large dykes of porphyry, and veins of quartz, the latter generally containing quantities of earthy iron ore with galena. From veins in this district, the author has taken some very fine specimens of hematite and magnetic iron ore, and iron pyrites. At no great distance from the village of Tempio, there is a vein containing antimony in considerable quantities, also a combined mineral, containing iron, antimony, and nickel, is found

in the same neighbourhood. The want of any sufficient means of transport has hitherto prevented any work being done in this district, but as the railway now in course of construction will pass along the valley from Ozieri to Terranova, it may be hoped that before long something will be done in it.

Further south, on the southern side of the Terranova valley, a lofty range of mountains extends the whole length of the island down to Cape Carbonara, the highest peak of which is the "Genargento," 5400 feet in height. These consist for the most part of granite, intersected by porphyritic dykes, and crystalline schists, also clays, limestones, and schists of Silurian origin. These formations are everywhere traversed by metalliferous veins. On the sea-coast to the eastward occurs a formation, apparently of secondary origin, consisting of coarse shelly limestone, forming the abrupt headlands of Monte Santo and Tavolara. Situated inland, about forty miles from the coast, near the village of Seui, and at a high elevation amongst the mountains, is a deposit of tertiary formation, in which occurs a bed of coal of superior quality to any found in other parts of the island, this will be again mentioned when treating of the subject of the coal formations.

Commencing from the northward, the first mine to be noticed is that of St. Theodoro, which was opened by the author last year. It is situated on the sea-coast about fifteen miles south of Terranova, almost on the junction between the granite and the schistose rocks. On the surface an outcrop of quartz with specks of galena was observed, the vein taking a north-westerly direction towards the granite, but not entering it. A shaft was sunk on the vein to the depth of 42 feet, at which point a pocket of about 8 tons of very pure galena was met with. A gallery is now being driven on the vein in the direction of the granite. The vein is irregular and very variable in width, and is at present yielding but little ore.

Almost in the centre of the island, near to the village of Ozieri, some traces of mineral have been met with in the metamorphic rocks, but beyond getting out a few samples, which on analysis prove to be of good quality, nothing has been done to prove them.

Due west from the last-mentioned place, also in metamorphic rock, but close to the granite, are the mines of Lulla, where a large vein of rich argentiferous galena is worked, to a certain extent, by a few Italians, but the difficulty of transport to the sea-coast, at Siniscola, is a great obstacle in their way.

Further south, on the edge of the granite eruption of the Genargento, but in the schistose rocks, is situated the valuable

mine of Corruboi, also the property of an Italian company. The vein here worked has a direction N.W.–S.E., and varies from 3 to 8 feet in width; it produces a very pure galena, which in some cases yields as much as 400 ounces of silver per ton. Such valuable ore as this of course pays for transport under difficulties, and the mine is in a flourishing condition.

To the southward of this, until the neighbourhood of Murravera is reached, there are at present no working mines, though traces and indications of mineral abound on every side. Throughout the whole country, inland, as far as the edge of the tertiary formation to the westward, there is scarcely a square mile in which mineral is not to be found. The peculiar eruptive formation around Tortoli and Lanusei, with its countless small veins and impregnations of mineral, will be mentioned under the head of mineral deposits in general.

The last mineralogical district to be mentioned is that of Murravera, in which are situated the valuable mines of Lilla Paredis, Arbus, and Gibbas. The latter mine has lately been drowned out, and the works have been stopped in consequence. Each of these mines has been producing very rich argentiferous galena, in large quantities, and their proximity to the sea-coast enables them to export their ore at a comparatively low cost. They are all situated entirely in the schistose rocks, the two former at a considerable elevation in the mountains, the latter, Gibbas, on the sea-coast and very little above the sea level. Besides these mines there are traces and indications of mineral, some of which have been partially explored, all over the neighbourhood.

Having thus briefly described the principal mining districts in the island, and noticed the mines really at work, and producing marketable mineral, at the present time, the author will now notice more particularly the various minerals which are found in the island, and also the formation and characteristics of the veins which produce them.

Lead, the ores of which form the larger and most valuable part of the mineral products exported from Sardinia, deserves the first notice. Passing over the comparatively small quantity of that metal which, as has already been mentioned, was extracted from the scoria at Domus Novas, the lead-producing minerals found in the island are galena and cerusite, or carbonate of lead. As the latter has, as far as the author has been able to ascertain, only been found in any workable quantity in two places in the island, namely, at Monte Maria, near the Rosas mine, and at the Gibbas mine, this brief notice will suffice. The general ore of lead is galena, which is found

under various conditions in all those parts of the island where mineral ground exists at all. The veins containing this mineral are met with in all the metamorphic rocks, and also in the granite, and continue from one into the other. Besides the regular veins, there are also several mines where the mineral is found in pockets of varying size and with no apparent connection. Pockets of mineral of this description are found more frequently in the limestone and schists of the Iglesias district.

Those disconnected lumps of galena met with in the granite of the Lanusei district are not so much pockets as impregnations, and have a distinct relation to the veins in the neighbourhood. Between the galena found in the metamorphic rocks and that found in the granitic and porphoritic rocks there is a very marked difference, the former being in almost all cases a fine-grained mineral, and the latter consisting of large cubic crystals, very friable and having a brilliant lustre. It is supposed by some that the galena with the smaller crystals has in it a greater amount of silver than that which crystallizes in large cubes, but the author finds that his experience, in Sardinia at least, is the opposite, for, whilst specimens of ore from veins of fine-grained galena in the limestone and metamorphic rock when yielding 75 per cent. of lead hold only from 5 to 40 ounces of silver per ton, samples taken from the veins in the granite of the Lanusei district, with the same percentage of lead yield over 200 ounces of silver per ton. In one instance, a specimen which the author took from a vein of the latter description gave, on analysis, 82 per cent. of very pure soft lead, and 680 ounces of silver per ton of ore. The mineral from the veins in the metamorphic rock is also very often found to contain a considerable quantity of blende, which in many cases no amount of mechanical dressing will separate from the lead. This intimate mixture of blende occurs very frequently in the mineral found in the district of Iglesias, indeed, in the case of the Rosas mine, it had much to do with the want of success which attended that undertaking, the best and most improved machinery failing to classify the constituents of the mineral. An analysis of a specimen of ore from this mine showed

Lead	42·80
Zinc	20·30
Iron	6·00
Sulphur	18·50
Magnesia	2·40
Silica	4·00
Lime	2·00
Oxygen and carbonic acid	4·00
	100·00

The axis of geological disturbance in the whole of the island of Sardinia lies between north and west, and the author has found from experience that the mineral-bearing veins almost invariably have the same direction. Those taking a north-easterly—south-westerly direction rarely prove profitable. It is in all cases difficult to lay down a hard and fast rule to guide the search for minerals, but when in one locality the same thing is found occurring many times, it may be expected that it will occur again. So local experience lays down a rule of its own. For an example which will serve for the whole eastern part of the island, a vein which the author traced and partially explored in the Lanusei district will suffice. Starting from the neighbourhood of the Corruboi mine, of whose sett of mineral it will most probably be found to form a part, and lying in the metamorphic rocks entirely, the vein in question takes a direction south-east. The width on the outcrop averages about 4 feet, and the dip is ten degrees from the perpendicular to the south-west. The gangue consists of quartz and barytine with earthy brown iron ore. The mineral is a comparatively fine-grained galena, of which the following is the analysis:—

Lead	76·40
Iron	3·20
Sulphur	13·60
Silica	1·00
Lime	2·80
Carbonic acid and traces of silver	3·00
	100·00

Silver, 54 oz. per ton.

The vein was explored only to a depth of from 10 to 15 feet in various places, and the average yield of mineral found to be about 10 lbs. per cubic yard. Much more than this may of course be expected as the workings advance in depth. This vein was followed under much the same conditions for a distance of nearly three miles, when it struck the granite and immediately underwent an entire transformation. The direction was deflected from south-east to nearly due east, and the vein split into several different branches, these gradually dying out until at about a mile from the point at which it entered the granite a few impregnations of mineral, varying in size from two or three pounds to a mere spot, were all that remained of it, and these finally disappeared altogether. The largest of these branches was about 2 feet in width, of very solid quartz, with small cavities containing gossan and crystals of silica, and the galena was concentrated into a small lode of from 2 to 6 inches in thickness very pure and clean, with large cubical

crystals of brilliant lustre. The analysis of a specimen taken from this part of the vein gave

Lead	82·20
Iron	1·50
Sulphur	14·00
Silica	1·00
Traces of silver, &c.	1·30
	100·00

Silver, 618 oz. 10 dwt. per ton.

The other branches into which the vein divided itself on entering the granite were by no means so rich, in some of them the galena being a mere trace. The richest and largest branch was the one which adhered most nearly to the direction of the original vein in the schist, making with it at the point of contact an angle of 150 degrees. The other radiations went off at acuter angles and were proportionately less metalliferous, smaller, and sooner fading entirely away. On following these in depth, but little change was to be observed. The explorations in them have not been carried to any considerable depth, but as far as they go they show them to be much the same as on the surface, and surrounded on every side by impregnations of galena such as have been described. The result of the study of this vein, which it must be remembered is only an example of many in the same and neighbouring districts, is that the following rule seems to establish itself, namely, that the part of a vein in the metamorphic rock, near to the granite is the richest in mineral, i. e. lead, but that the broken-up parts of the vein in the granite are richer in silver.

The cause of this breaking up of a vein when passing from one formation into the other, may possibly be found in the supposition that the granite in this district is of somewhat more recent date than in other parts, as its semi-porphoritic appearance seems to indicate, and thus being erupted at a time when the sedimentary rocks had cooled to a certain extent, it caused in them very violent dislocations, which are apparent, and also in the consequent rapid cooling of itself the cracks were formed which afterwards being filled with mineral matter formed the veins in question.

Next to lead, the most valuable mineral found in the island of Sardinia in workable quantities is calamine, and this is found only in the Iglesias district. As far as is known to the author, calamine has not yet been met with in any of the eastern districts of the island, though it has been diligently searched for in the more accessible regions near the sea-coast. It is worked

to a great extent at the mines of Vieille Montagne near to Iglesias, Duchessa in the Oridda Valley, and many others. In these mines it occurs in immense masses, indeed the Vieille Montagne more nearly resembles a quarry than a mine. The mineral is generally roasted on the spot, and then shipped at Carlo Forte and Cagliari for the smelters at Swansea and other places. There are no remarkable features in the occurrence of calamine worth mentioning. A specimen from the Duchessa mine gave the following analysis:—

Zinc	54·80
Iron	1·10
Lead	·20
Silica	1·80
Alumina	·20
Carbonic acid, &c.	41·90
	100·00

The export of calamine from Sardinia in the year 1877 was reported to have exceeded 60,000 tons.

Iron is the mineral which comes next under consideration. The low price which this metal has commanded during the last few years has almost closed this branch of mining in Sardinia. When, as at present, the rich ores of Elba, notwithstanding their great advantages regarding shipment, will scarcely pay for working, the Sardinian ores have no chance in the market. The only iron mine at present at work in the island is the San Leone, situated in the granite formation on the west side of the Bay of Cagliari. A large deposit of magnetic iron ore of very fine quality is here worked by a French company. Many schemes have been advanced for smelting iron in the island, as there is plenty of fuel in the forests, the property of the Government and the communes, but for some reason it has never been seriously started. Indeed the lead-smelting works which were once established at two or three places in the island did not give any encouragement, as they have all been closed. Iron pyrites, specular ore, and hematite, have all been discovered in the mountains of the north-eastern part of the island, but have not been opened up, nor have the deposits even been properly examined.

Copper, in the form of pyrites, and blue and black copper ore, has been found in several parts of the island; but, as most of the deposits were opened up by explorers without the necessary capital to carry on the work to success, and also as they are for the most part situated in the most inaccessible parts of the island, no mines of any consequence have ever

been opened, and at present, owing to the general fall in the price of metals, even the explorations have been adandoned. On the eastern side of the island, not far from the village of Bouné, there is a deposit of copper ore known as the Frondio mine, which has been partially explored, but the works are now at a standstill. A large vein of quartz, and the usual veinstuffs, with copper and iron pyrites, blue carbonate of copper, and traces of galena, are to be seen cropping out on the side of a steep hill of Silurian and metamorphic formation. The vein lies N.W.–S.E., and appears to be perpendicular and 8 to 12 feet in width at the outcrop. The works consist only of a trench cut in the vein about 10 feet in depth, and a heading commenced to cut the vein at a depth of about 50 yards from the outcrop. This heading had been driven some 30 yards towards the vein, but had not reached it when the work was stopped.

Of the metallic ores there remain now only antimony, manganese, and blende to be noticed. Traces and indications of these minerals abound in several parts of the island, and the author has collected many fair specimens in his wanderings through the mountainous districts of the eastern part, but as yet they have not been worked, nor have these localities been properly explored. Antimony exists near the village of Villa Salto, and also not far from Sisini, in the south-eastern part of the island. There is also a vein with antimonite (tersulphide of antimony) a short distance from the village of Tullo in the district of Tempio, to the north. In other parts of the island specimens have also been found.

Manganese, in the form of the black oxide, has been found in the Silurian formations near to St. Basilio, in the south-eastern, and also not far from Bosa, in the western parts of the island. In the Lanusei district the author has also found some curious specimens in which the threads of oxide of manganese in limestone rock have the appearance of impressions of leaves.

Blende has already been mentioned as forming a very deleterious ingredient in the lead ores at some of the mines in the Iglesias district. It occurs in all parts of the island, always in intimate combination with other minerals. Nowhere in the island has it been found sufficiently pure to be worked at a profit. The mineral veins in the argillaceous schists and limestones of Silurian formation contain a far larger quantity than those in the granite.

Having thus reviewed the metalliferous productions of Sardinia, the author now comes to the almost equally important one of coal. During the years preceding the present depression of

trade, when English coal, and also freight for it to the Mediterranean, commanded high prices, a great deal of interest was evinced in the subject of the coal and lignite deposits of the countries bordering on the Mediterranean, and amongst others the carboniferous deposits of Sardinia, the existence of which had long been known, were brought into prominence. The central position in the Mediterranean of the port of Cagliari, possessing a magnificent harbour, renders it a most appropriate place for a coaling station, and if coal of such a quality as would be suitable for use in sea-going steamers could be got within easy reach of this port the working of it would not fail to be a profitable investment. This was so manifest that considerable attention was given to it and reports on the Sardinian coalfields became plentiful. The author at that time went to Sardinia to examine and report upon these coal deposits for Messrs. Docwra, who were the contractors for a railway then being made in the island. He took with him adequate boring tools and experienced English workmen, so that nothing might be wanting necessary to secure a thorough and exhaustive examination.

It has already been mentioned that a large alluvial valley runs through the island, with an arm extending to Iglesias on the south-west, and dividing in the northern part towards Portotorres and Terranova respectively. Beyond the town of Iglesias, towards the sea, lies what is generally known as the Gonnesa coal basin, a large tertiary deposit of about six miles in length by four in breadth. It is in this that the coal was first discovered, and here are situated all the pits which have ever been worked at a profit. The principal pits are Bacuabis, Cortighiana, Terra di Collu, Fontenamare, and Barbusi. They are worked by various persons and companies, and are all in the same formation and very closely resemble each other. A section of the formation at the Barbusi mine accompanies this paper. The coal is both covered and underlaid by a yellow argillaceous limestone, tough and compact, and forming a good roof for the workings. The largest seam of coal found at this place was 4 feet 8 inches in thickness, about 3 feet only of the centre being good clean coal. The outside of the seam both above and below was very shaly and dirty. All the lower seams were found to be of an inferior quality to the upper one. The tertiary deposit, of which the Gonnesa coal basin is formed, is surrounded on three sides by mountains of Silurian origin, and on the west it is bounded by an eruption of trachyte and by the sea. The coal beds are more regular, and thicker when nearer to the older rocks; going from them they

gradually thin out until towards the centre they die away entirely; the eocene limestones and clays resting thinned out on the Silurian rock and being covered with a deep alluvial deposit.

Near the town of Iglesias, a broad band of Silurian rock cuts off the valley, and tertiary formation of Gonnesa, from that which extends from Iglesias to Cagliari. In this latter valley the author put down a line of borings, in order to ascertain the formation underlying the alluvial deposits which are the surface of these valleys. No trace of coal was met with in the centre of this valley. A boring at Musei, 330 feet in depth, passed through alternating beds of argillaceous limestone and marly clay, until, at the depth mentioned, it reached the crystalline rock of the bottom of the valley, but no trace of coal was met with, and borings in the direction of Cagliari and Oristano had the same result. But around the sides of these valleys, at Iglesias, Villamassagia, Domus Novas, San Gavino, Marrubiu, and several other places, traces of coal have been met with, but of small size and very inferior quality. So many reports had been put in circulation, regarding vast coalfields, extending over the whole of these large valleys, by various engineers visiting the island (some of whom had gone as far as to estimate the amount and value of the coal which they supposed existed), that it was necessary to be exceedingly careful in exploring, and the author critically examined every place where it was possible coal formation could exist, and he has arrived at the conclusion that except in the valley of Gonnesa there exists very little workable coal in the island, and also that all the coal which exists has been quietly formed in the bays of ancient seas, under the shelter of the more ancient rocks. The outlying portions have been denuded away by the waters which afterwards covered the beds of coal, and the strata which contains them, with alluvial deposits. In the centre of the mountains towards the east, from the village of Seni south-east to Ulassi, there is a chain of small tertiary deposits, at a high altitude, overlying, and surrounded by crystalline schists, which contain seams of coal resembling anthracite, of very fair quality and varying from 2 to 5 feet in thickness. Their inaccessible position, however, renders them at present useless, so that beyond a small exploration no work has been done on them.

In appearance this Sardinian tertiary coal has a certain resemblance to the true coal of the carboniferous system, being hard, compact, and perfectly black, but with a decided conchoidal fracture. It burns with a long, bright smoky flame

and a sulphurous odour, it contains a considerable amount of gas, and leaves a soft loose-grained coke and not a large quantity of ash.

An analysis of a specimen of coal from the Terra di Collu mine showed

Carbon	41.50
Volatile matter	48·00
Sulphur	3·60
Residue	6·90

By the kind permission of the secretary of the company some comparative experiments were made at the Fulham Gasworks with this coal, of which the following is the result:—

THE RESULT OF EXPERIMENTS MADE WITH SARDINIAN COAL COMPARED WITH A SCOTCH AND TWO ENGLISH COALS.

	Sardinian.	Scotch.	Newcastle.	Lancashire.
Cubic feet of gas per ton	9500	8900	10200	12500
Coke .. .. .. per cent.	56	58	67	65
Heating power .. units	12493·64	12764·40	12986·00	13296·65
Specific gravity	1·202	1·275	1·265	1·240
Ash in coal .. per cent.	6·47	9·16	4·20	5·44
„ coke .. „	11·50	14·18	6·50	8·06
Sulphur in coal .. „	3·35	2·64	1·50	2·00
Power of gas .. candles	15	16	16	20

The experiments from which the above table was formed were conducted with every care, and the result may be taken to establish the value of the Sardinian coal as compared with the others, but it must be remembered that the sample used was a very good one, and also that laboratory experiments will always give better results than can be expected in actual practice. The value of the coal as a marketable article depends on its proportionate value compared with the English coal with which it has to compete. As a gas coal, though it contains a large quantity of gas, it is nearly useless on account of the large per centage of sulphur it contains. A trial of it made in the gasworks at Cagliari had most unpleasant results. As a steam coal it has been used, and with a certain amount of success, but since English coal has fallen in price, the use of Sardinian coal, both on the railway and by steamers, has been abandoned. The disadvantages are, That its heating power is not equal to that of English coal; that it takes considerably more room for stowage of an equal weight; with a strong draught it burns away too rapidly; and also the sulphur is very

deleterious. Altogether it may be taken at 60 per cent. of the value of English coal (in cases in which it can be used at all), so that when English coal in Cagliari cost 50*s.* per ton and the Sardinian coal 20*s.*, there was, taking it at the above ratio, a saving of 10*s.* per ton. But now that the English coal can be delivered there at 25*s.* or less, the inferior article is quite out of the market for steam purposes. For foundry use, for roasting calamine, and other purposes of a like nature in the island, it is still in considerable demand; and, should the true coal of northern countries again rise to anything like its former price, Sardinian coal may still have a useful future in store for it. The island of Sardinia itself, when opened up by railway and road construction, and its proverbial unhealthiness dispelled by cultivation, will in time take its place as one of the most fertile islands, and one of the richest mineralogical countries in Europe.

APPENDIX.

LAWS, DECREES, AND REGULATIONS RELATING TO MINING OPERATIONS IN THE OLD KINGDOM OF SARDINIA.

Translated from the Italian by CHARLES J. ALFORD, M.S.E.

Law of November 20th, 1859. *No.* 3755.

Article 1.

Supervision of Mines by Government.

All matters relating to mines, quarries, and workings are placed under the jurisdiction of the Minister of Public Works.

Article 2.

The territory of the State is divided into seven mineralogical districts, as per Table A attached to the present law. The number and constitution of these districts are able to be varied by a Royal Decree, should it be necessary to do so for the good of the State.

Article 3.

Every mineralogical district will have an office presided over by an Engineer appointed in the same manner as all other Civil Engineers of the Government, and he will be assisted by another technical employé.

ARTICLE 4.

The Minister of Public Works will appoint an Inspector of Mines, selected from the Engineers, who will have under his orders one or more assistants.

ARTICLE 5.

The duty of these Engineers is to see that the law, and the regulations of the Minister are properly carried out in their respective districts. To this effect they will, on their annual visits, also in the extraordinary inspections, carefully observe the manner in which the work of all mines and quarries is being conducted, both with regard to the security of persons, and also to the proper working in the interests of both the Government and the proprietors.

They will also inspect, in the interests of public health and safety, the establishments and workshops used for the preparation of the product of the mine or quarry.

They are obliged to report any infraction of the present law which they may happen to find out.

ARTICLE 6.

A regulation approved by Royal Decree will determine the conditions of the first admission of persons into this special service, and their subsequent duties.

ARTICLE 7.

The Council of Mines.

A "Council of Mines" is to be instituted under the superintendence of the Minister of Public Works. This Council will be composed of not less than six, or more than eight members, selected from the legal members of the "Council of State," from the members of the "Royal Academy of Sciences," and of the "Royal Institute of Science, Letters, and Art." Also from among persons skilled in mining and mineralogy.

The Inspector of Mines will become a member of the Council, ex officio.

An official of the Minister of Public Works will be appointed Secretary to the Council.

ARTICLE 8.

The members of the Council of Mines shall be nominated by the King.

They remain in office six years.

Every three years half are removed, but may be re-elected.

At the first triennial meeting it shall be decided by lot which of the Council may be re-elected.

ARTICLE 9.

The Minister of Public Works will be ex-officio President of the Council.

A Vice-President will be elected by the members and nominated by the King every year.

Article 10.

The Council will give its opinion in cases determined by the law, and will always meet at the request of the Minister. It will also be called upon to prepare projects of instruction and the regulations necessary to ensure the proper execution of the law and regularity of the service. The vote of the Council is "consultino" (not decisive until confirmed by law).

The vote and opinion of the Council is always to be accompanied by a statement of the reasons on which it is based.

Article 11.

Members of the Council resident outside the capital, will be paid their travelling expenses, as allowed by the Inspector of the Civil Service.

Article 12.

No member of the Council shall have any interest directly, or indirectly, in any mine or other work coming under the jurisdiction of this Act.

The Government Engineers are not, under any circumstances, allowed to take part in any mining operations or work of any kind in their respective districts, which comes under this Act, or under the jurisdiction of their respective offices.

Article 13.

Classification of Works.

The working of mineral substances affected by the present law is divided into two classes.

Class 1.—Mines consisting of veins, beds, or masses of mineral from which are extracted gold, silver, platinum, iron, copper, lead, zinc, tin, antimony, arsenic, bismuth, cobalt, nickel, mercury, manganese, and other metals; sulphur, sulphate of iron, sulphate of copper, sulphate of zinc, sulphate of magnesia, and sulphate of alumina; also alumina, bitumen, asphalt, graphite, antracite, coprolites, and lignite.

Quarries.

Class 2.—Comprises peat diggings, quarries of sand and fireclay, of stone for construction purposes or ornament, limestone, plaster of Paris, slates, potters' clay, millstone, brick earth, clays and marls of various kinds, pozzolana, gravel, ballast, quartz, barytine, fluorspar, and all other rocks and minerals that are not themselves metals or the product of metals or combustibles, or comprised in the beforementioned first class.

ARTICLE 14.

Salt.

The present law is not to be applied to salt, either mineral or evaporated.

ARTICLE 15.

Regulations regarding Minerals comprised in Class 1.

No mine may be worked (venire cultivato) except under a Royal Concession.

From the date of the Act of Concession, the mine becomes a new property, perpetual, disposable, and transferable like any other property, excepting only when the power of transfer is limited by the Act of Concession.

ARTICLE 16.

Mines are "Beni immobili" (not removable from under the jurisdiction of Italian law), so also are all buildings, machines, shafts, galleries, and other works appertaining thereto in conformity with the Civil Law.

ARTICLE 17.

All plant used on the mine are considered to be "Beni mobili" (removable from under the jurisdiction of the Italian law), including also horses used in the interior of the mine.

ARTICLE 18.

Material extracted, stones, and other portable articles, are "Beni mobili."

ARTICLE 19.

Shares in any company or interest formed to work a mine are "Beni mobili."

ARTICLE -0.

On the Exploration and Opening up of the Mine.

Those persons only are considered to be the explorers of a mine, in the sense and for the effect of this Act, who have a permission to undertake it from the Government.

Permission of Exploration.

The said permission may be obtained without the consent of the proprietor of the land.

ARTICLE 21.

Any person wishing to obtain the permission to explore for minerals shall give to the "Intendente del Circondario" a demand, stating

Name and address of applicant in full.

Minerals for which exploration is to be made.

Situation and limits of the place in which the exploration is to be made.

Nature of work proposed to be done.

Name in full, and residence of the proprietor of the land.

When the exploration is to be made in a place which has not before been touched, a declaration of the consent of the proprietor is to be attached to the demand, if such consent can be obtained.

Article 22.

The "Intendente" will order the publication of the demand in the commune wherein the place in question is situated, and this publication is to be made for not less than ten days, during which time any persons who have any objection to make to the granting of the permission, are to present their reasons for so objecting, at the office of the "Intendente."

At the expiration of this time the Engineer of Mines will give his opinion as to the probable success of the exploration, and on the conditions which he considers should be imposed on the explorers, before or after the presentation of the plans, which after the advice of the Engineer may be ordered by the "Intendente."

The "Intendente" will then send the application, with all papers relating thereto, to the Governor of the Province, who will, after due examination, give, or refuse, the permission of exploration.

Article 23.

Against the Decree of the Governor of the Province, application may always be made to the Minister of Public Works, whose decision is final.

Article 24.

The permission of exploration will be given for a certain time, which in any case is not to exceed two years.

If at the expiration of this time the mine has not been sufficiently explored, the permission may be renewed for one year.

Article 25.

The Governor of the Province has power to revoke the permission in case the work of exploration is not commenced within three months after the date of the Decree giving it, and also if the work be not proceeded with during any three consecutive months whilst it lasts, unless such stoppage of work be caused by "Force majeure."

Article 26.

The Decree giving the permission, and if it be revoked, the Decree revoking it, must be published in the same manner, and in the same place as was the demand.

Article 27.

The explorer must have a legal residence in the neighbourhood of his works.

ARTICLE 28.

The explorer may not sell or transfer his permission to any other party, without making a declaration to the "Intendente."

This cession, or sale, will in no case relieve him from his personal obligations and charges regarding the permission.

The person to whom the permission is ceded or sold, must also have a legal residence in the district.

ARTICLE 29.

The explorer will be obliged to pay all damages caused by the work of exploration, Articles 78, 79, 80, 81, and 82 of the present law being applicable also to him.

The proprietor of the land on which the exploration is to be carried on, may oblige the explorer to give adequate security of his ability to cover damage done, either by agreement made before a notary, or by a deposit of money or Government stock.

If the parties cannot agree, the "Intendente" will, after taking legal advice, fix by Decree the amount of deposit, which done, the work may commence.

ARTICLE 30.

Any other disagreement between the explorer and the proprietor of the land regarding the validity of the agreement, or the amount of the security, shall be settled by the Courts of Justice.

ARTICLE 31.

No permission of exploration will give the right to explore in any place surrounded by a wall, in courtyards or gardens, without the formal consent of the proprietor. Nor will it give a right to bore, sink shafts, or make galleries or tunnels within 100 metres of any dwelling house, or any place surrounded by a wall appertaining to the said dwelling house, or within 40 metres of any other place surrounded by a wall.

The proprietor of the land exploring on his own property must observe the same law with regard to places belonging to others.

ARTICLE 32.

Works of exploration are not to be undertaken within 20 metres of the public road, or in land which overhangs or is under any public road, without a special leave from the "Intendente," who, on the advice of the Engineer of the Government, will order the precautions necessary for public security.

The same dispositions are applicable if explorations are undertaken within 100 metres of any canal, aqueduct, watercourse, or mineral spring.

ARTICLE 33.

No proprietor of the land is allowed to explore for minerals within the limits of any concession, without the permission of the Con-

cessionnaire, or, if such permission cannot be obtained, without an authorization from the Government.

Such an authorization may be given by a Decree of the Minister of Public Works, after Articles 21 and 22 have been complied with, and the case heard by the Council of Mines.

ARTICLE 34.

The explorer is not able to dispose of any mineral extracted, without having obtained an authorization from the Government.

ARTICLE 35.

When the existence of the mine, and the possibility of its being worked are sufficiently proved, the Governor will, on the demand of the explorer, commission the Government Engineer of Mines to visit the place and to make a report thereon, when the mine may be declared opened and concessionable by a Decree of the Minister of Public Works, after hearing the report of the Government Engineer, and the opinion of the Council of Mines.

ARTICLE 36.

After the mine is declared opened, until the concession be given, the explorer may continue work, conforming to any conditions which may be given him.

ARTICLE 37.

Any contravention of Articles 27, 28, 31, 32, 33, 34 will be punished by a fine of from five to fifty francs, without prejudice to any indemnity which may be claimed by injured parties.

ARTICLE 38.

The Concession of a Mine.

Any individual, whether he be a citizen of the State or not, or any company legally constituted may obtain the concession of a mine, provided they can prove themselves able to carry on the work, and to undertake the obligations imposed by the Act of Concession.

The concession may be given to more individuals than those making the demand, in which case they will be individually and collectively responsible for all the obligations which may result therefrom.

ARTICLE 39.

The concession may only be had of mines which have been declared opened and are otherwise concessionable.

ARTICLE 40.

The persons who opened up the mine, or their rightful successors, will have the first right to the concession of the mine; the Administration seeing that the conditions of Article 38 are fulfilled. The persons wishing for a concession must, within six months after the mine has been declared opened under Article 35, present their

demand for the concession in the form prescribed by Article 42. Should the six months be allowed to pass without the demand being made, unless under conditions settled by the Administration, the Minister of Public Works will, on the advice of the Council of Mines, issue a Decree declaring the parties to have forfeited all right to preference in obtaining the concession. In this case the opener of the mine may have a right to some payment which will be charged to the Concessionnaire and will be determined by the Act of Concession. This payment will always be determined as regarding the value of work done, and not as the value of mineral extracted and left disposable on the mine.

Article 41.

After the issue of the Decree mentioned in the preceding Article, the Governor of the Province will give public notice that the mine is to be concessioned.

The publication of this notice is to be made in conformity with Article 43, and must indicate the nature and situation of the mine.

Article 42.

Every demand for a concession will be addressed to the Governor of the Province in which the mine is situated.

This demand must be accompanied by a correct plan on which the limits of the required concession are distinctly shown. This plan is to be made on a scale of not less than 1 in 4000. The applicant must also present the necessary documents to prove that he is eligible to receive the concession, as required by Article 38.

Article 43.

After the Government Engineer of the district has certified to the correctness of the plan, and recognized the limits of the required concession on the ground, the Governor will order that the demand be published for three consecutive weeks in the chief town of the province at the door of the office of the Intendente, and in all communes in which the limits of the desired concession lie, also that it be published in the leading newspapers of the province, and in the official print of the kingdom, all the charges for publication being borne by the applicant.

The certificate that this publication has been made is to be attached to the demand.

Article 44.

Within thirty days after the last of the publications prescribed by the preceding Article, the Intendente will receive all persons opposing the demand, and take down a statement of their objections in a particular register. These objections will be notified to the parties interested, and a time fixed for them to be answered. This register, and all other matters relating to opposition, will be open to inspection at the office of the Intendente.

ARTICLE 45.

Should other parties make a demand at the same time for a concession of the same place, it will be treated as simply an opposition to the other, except so far as it relates to land not comprised in the limits of the other, in which case it will be considered as a new demand.

ARTICLE 46.

At the expiration of the thirty days, as per Article 44, the Intendente will take advice of the Government Engineer of Mines of the district, and will then forward the demand, with his opinion thereon, and all matters relating thereto, to the Governor of the Province, for the proposition to be made to the Minister.

ARTICLE 47.

Any opposition will be admissible before the Minister up to the time of the issuing of the Royal Decree for the concession.

Notice of opposition will be given to the parties interested, who will be able to reply.

ARTICLE 48.

Any opposition made against the demand on the part of a previous Concessionnaire, or his legal successors, will be referred to the ordinary Tribunal.

ARTICLE 49.

When there is no opposition, or when it has been settled, a definitive concession will be given by Royal Decree, after the opinion of the Council of Mines has been taken, and the matter heard by the Council of State.

ARTICLE 50.

The Royal Decree of the concession will indicate the full name, profession, and residence (which for all legal purposes must be in the district in which the mine is situated) of the Concessionnaire; also the situation and nature of the mine, the proposed mode of working, the amount payable to the Government, as per Article 59. Also all other obligations and duties which the Concessionnaire is to take upon himself by virtue of the concession.

The Royal Decree will also fix the extent and limits of the concession, which in no case is to exceed 400 hectares, and this is to be accurately and distinctly drawn on a plan which is to be attached to the Act of Concession.

ARTICLE 51.

One Concessionnaire, whether he be a private individual or the representative of a legally constituted company, may obtain any number of concessions with the obligation of holding them all in active work.

ARTICLE 52.

The Concessionnaire must, within three months from the date of the Royal Decree, pass before the Intendente of the district an act of

submission to the conditions imposed by the concession. Whenever the Concessionnaire is not also the actual opener of the mine, he must produce a certificate that the opener of the mine has been satisfied, or, that a sum of money has been deposited equal to the indemnity required by the Act of Concession. (See Article 40.)

ARTICLE 53.

The accomplishment of the deposit stated in the preceding Article will give a full right to the concession.

ARTICLE 54.

The Royal Decree of the concession is to be published at the expense of the Concessionnaire, in all the communes wherein the mine lies, and to be entered in the registers of the same.

ARTICLE 55.

Working a mine without having first obtained the concession will be punished by a fine of from 50 to 500 francs, without prejudice to the confiscation of the mineral extracted, or to the recovery of damages by other parties.

ARTICLE 56.

This publication and delimitation is also required on the part of the Government when they intend to undertake the working of a mine on their own account.

ARTICLE 57.

From the day on which the concession of the mine is given, the mine becomes an entirely separate property from that of the surface ground.

ARTICLE 58.

On the Obligations and Rights resulting from the Concession.

Every right and privilege resulting to the proprietor of the mine from his concession, is like the mine itself a property "immobili" (not removable from under the jurisdiction of Italian law). (See Article 16.)

ARTICLE 59.

Every concession will pay annually to the Government a fixed tax and also a proportional one.

ARTICLE 60.

The fixed tax will be fifty centesimi for every hectare of superficies over which the concession extends, and is in no case to be less than twenty francs.

ARTICLE 61.

The proportional tax will be five per cent. of the net produce of the mine, and will be determined every year by the Government on the proposition of the Engineer of Mines.

The net product of the mine is the value of the extracted mineral, deducting the expenses of working the mine, preparation of the ore for sale, of transport, and of ventilation and drainage of the mine. The expenses of administration, of construction, interest on capital, and all outlays of that description are not to be deducted.

ARTICLE 62.

The proportional tax may be converted, for a specified time, into a fixed payment.

A convention to this effect made between the Minister of Finance and the Concessionnaire of the mine, with the approval of the Minister of Public Works, will be approved in the form prescribed for contracts with the Central Administration.

ARTICLE 63.

The Government have power to remit the proportional tax, in total or in part, in consideration of the proprietor of the mine having incurred heavy extraordinary expenses in working, or having suffered losses by accident not occuring from any negligence or fault in the working. Such remittance of tax is to be made by Royal Decree after the application has been heard by the Council of Mines and the Council of State.

ARTICLE 64.

The Concessionnaire will keep a register of the quantity and value of the mineral extracted from the mine, and also regular accounts of all expenses incurred in the extraction of such mineral. These accounts and registers will be open to the inspection of certain officials. In the month of January of each year the Concessionnaire will send to the Intendente del Circondario, an extract of these accounts on a form prescribed by the Administration.

ARTICLE 65.

The Concessionnaire will make (on a scale of 1 in 500) two plans of all work done in the mine, one of which will be sent to the Government Engineer of the district.

In the month of January of each year these plans are to be fully marked up and compared.

ARTICLE 66.

The Concessionnaire, by not sending in the accounts and plans, as required by the preceding Articles, renders himself liable to a fine of from 5 to 50 francs, and in case of any falsification of either of them, to a fine of from 51 to 500 francs.

ARTICLE 67.

The Concessionnaire, worker, or manager of the mine, will give to the Government Engineer all facilities for inspecting the workings of the mine, and also the plans and accounts, as mentioned in Articles 64 and 65, and will give him all necessary information

relating to the working of the mine. In case of any refusal the Concessionnaire will be liable to a fine of from 51 to 200 francs, and the Engineer may call in the assistance of the local authorities and the police.

ARTICLE 68.

On Dividing a Mining Property.

A concessioned mine may not be sold, let, or divided without an authorization given by Royal Decree on the opinion of the Council of Mines and the Council of State.

ARTICLE 69.

Should the heirs of a Concessionnaire desire to keep the mine as a joint property, the work must be put under one direction, and the mine worked as one interest, as required by Article 72.

ARTICLE 70.

If the Concessionnaire or his heirs wish to divide the mine, they must present to the Intendente a demand accompanied by a plan of the ground on a scale of not less than 1 in 4000, and a plan of the workings of the mine on a scale of not less than 1 in 500.

The Intendente, after having procured all the necessary information on the subject, will send the demand, with all papers relating thereto, and the opinion of the Government Engineer of the district, to the Provincial Governor, who will forward the same, with his opinion thereon, to the Minister of Public Works, who, after the matter has been heard by the Council of Mines and the Council of State, may recommend the division to be approved of by Royal Decree.

ARTICLE 71.

The Royal Decree will determine the manner of the division, the work belonging to each division, and the parts of the taxes and other obligations allotted to each of the parties.

After the passing of the Royal Decree, the parties concerned must give in an act of submission thereto, in conformity with Article 52, when they will be considered as separate Concessionnaires.

ARTICLE 72.

Representation of the Proprietors.

Whenever the concession of a mine belongs to a company or to diverse persons, they must show, at the request of the Governor, that they have made proper arrangements whereby all the works are put under one direction and are worked in one interest, and also that their representative has been properly nominated with power of attorney before the Secretary of the Intendente. If within the time allowed by the Governor, the above regulation be not complied with, the Minister of Public Works may order the suspension of work on all

or any part of the concession, and if necessary appoint a person to administer the property on account of the Concessionnaires and at their expense.

Article 73.

Joint Working of Separate Concessions.

When from the fault of one system of working not being followed in mines adjoining one another, but included in separate concessions, the work is not being carried out properly, or any danger is incurred to persons, the work of these parts of the mines may be put under one direction by a Government order, made by Royal Decree on the opinion of the Council of Mines and the Council of State, after hearing the interested parties.

The interested parties may, if they can agree, nominate the Administration of the part in which they had a common interest.

In event of the interested parties not being able to come to any satisfactory conclusion as to the method of joint working, then the Minister of Public Works will appoint an officer at their expense, who will carry on the work of the part in question in such manner as may be determined by the Council of Mines. The Minister will in this case also provide for the proper division of the expenses and profits of the part in question among the parties interested.

Article 74.

To enforce the carrying out of the preceding Article the parties may be summoned before the law courts, but the work is not to be suspended.

Article 75.

Public Works.

Whenever from any cause the workings of one mine are damaged by the working of another, or in case work done in one mine becomes useful to another mine, by draining water, or any other cause, then the one Concessionnaire may demand compensation of the other.

Article 76.

In case of any work necessary for public security, or for the security of the mines being necessary, the same may be required to be done jointly by the Concessionnaires concerned.

Article 77.

The combination for carrying out works as per preceding Article will be established by Royal Decree, after the matter has been heard by the Council of State and the Council of Mines: and in every case the Administration may proceed against the parties interested.

ARTICLE 78.

Damages.

The Concessionnaires of mines are in every case responsible for damages caused by their works.

ARTICLE 79.

In the case of work of long duration, and where it is not possible in one year to restore the land to its original condition, the indemnity may be assessed as double the nett product of the land damaged or provisionally occupied. Whenever the occupation of land for works shall exceed one year the proprietors may oblige the Concessionnaire to purchase the same.

ARTICLE 80.

The proprietor of the surface ground may oblige the Concessionnaire to acquire the whole of any piece of land which may have been in great part damaged by the working of a mine.

ARTICLE 81.

If the workings of a mine extend under any habitation, under any closed place, or under the workings of any other mine, or in their immediate vicinity; the Concessionnaire may be obliged to lodge caution money as a guarantee against possible damage.

ARTICLE 82.

The Concessionnaire may obtain back his caution money as soon as he can prove that his work has been carried out without any damage having occurred.

ARTICLE 83.

Any works which may be necessary to be made outside the limits of the concession for the adequate drainage or ventilation of the mine may in certain cases be declared works of public utility and regulated by the laws relating thereto.

ARTICLE 84.

Security of Mines.

Whenever from any cause damage to life or property is to be feared, the Government Engineer will on his becoming aware of the fact, make a report to the Government giving his opinion on the means which should be employed to avert the same.

ARTICLE 85.

The Governor will then summon the proprietor of the mine, and state to him what measures he considers necessary to be taken. In case of any resistance on the part of those interested, the Decree of the Governor may not be enforced without the approval of the Minister.

The Governor may in the mean time, at the instance of the Engineer, order the work of the mine to be suspended.

ARTICLE 86.

Whenever the Government Engineer may find that the workings of a mine are in such a condition that it is not possible properly to provide for the security of persons, he will make a report on the subject to the Governor of the Province, who will summon the proprietors of the mine and hear their explanation.

Should the proprietors refuse to obey this summons, the Governor may order the mine to be closed, and proceed against them with the assistance of the Engineer. The observations and judgments of experts are to be embodied in "proces verbal," which the Governor will send to the Minister of Public Works, accompanied by his opinion on the case. The Minister, after the matter has been heard by the Council of Mines, will pronounce definitively.

ARTICLE 87.

Should the proprietors of the mine not conform to the abovementioned Act during the time fixed by the Act, the Intendente may instruct the Government Engineer of the district to take charge of the mine, and carry out the necessary work at the expense of the proprietors. In this case the mineral extracted, or found on the mine, or in the magazines, may be sold to pay expenses.

ARTICLE 88.

Children under the age of ten years are prohibited from going into, or working in any mine under a penalty of from 5 to 10 francs.

ARTICLE 89.

Accidents.

In case of any accident, by which any person is killed or dangerously injured, occurring in a mine or in any place connected therewith, the persons in charge are immediately to inform the Sindac of the commune, and the Government Engineer of the district.

ARTICLE 90.

The same information is to be given, in case of an accident compromising the safety of the workings of the mine, or the surface property. The contravention of either of the preceding Articles will be punished by a fine of from 5 to 50 francs.

ARTICLE 91.

In every case the Engineer is to go to the place and, either by himself, or with the assistance of the Sindac, or other officials, make a "proces verbal" on the accident, stating the causes which occasioned it.

The Sindac or police officers may nominate some expert to visit the works and support their opinion in the "proces verbal," which is then to be sent to the Governor of the Province.

ARTICLE 92.

Whenever the Sindac or police officers are informed in any manner that a serious accident has occurred, they are at once to report the matter to their superiors, and, with the assistance of the Government Engineer, if he be present, take all necessary measures to guard against further danger. For this purpose, they may use the tools, horses, and men of the mine, and have power to give the necessary orders. The work necessary to secure public safety is to be put under the direction of the Government Engineer, or, in his absence, under some competent person appointed by the Intendente.

ARTICLE 93.

The proprietor or manager of any mine, near to that in which an accident occurs, must give every assistance in his power. By neglecting to do so he renders himself liable to a penalty of 50 to 300 francs, without prejudice to any action for indemnity.

ARTICLE 94.

The expenses of attending to wounded men, repairing damages, and every other expense resulting from any accident is to be borne by the proprietors of the mine, without prejudice to any action for damages, or to the recovery of fines.

ARTICLE 95.

The proprietors of a mine are required to keep on the spot all necessary medicines and appliances for giving assistance in case of accident, and also to keep in their pay a surgeon; in conformity with orders which, regarding various cases, will be given them by the Administration.

One surgeon may attend several mines, when they are in a convenient vicinity to each other.

Contravention of the orders of the Administration on the above points, will be punished by a fine of from 50 to 200 francs.

ARTICLE 96.

On the Abandonment of a Mine by Express Declaration.

When a Concessionnaire or proprietor of a mine wishes to abandon the same he must make a formal declaration to that effect, to the Governor of the Province, which will be inscribed in the registers mentioned in Article 44 of the present law.

ARTICLE 97.

No conditions whatever are to be attached to the above declaration.

ARTICLE 98.

From the day on which the declaration mentioned in Article 96 is presented, the proprietor is not allowed to make any more excavation in the mine or to alter its state. He must also leave intact all work

necessary to the preservation of the mine, and the means of getting access to the workings, but should the mine be concessioned anew to another person, the original holder may recover from him the value of work so left.

ARTICLE 99.

The contravention of the above Article will be punished by a fine of 100 to 500 francs, and the offender may also be compelled to restore the mine to its original condition.

ARTICLE 100.

Immediately that the declaration required by Article 96 is registered, the Governor is to order the Government Engineer of the district to proceed to the place and make a complete report thereon, verifying the plans of the workings, and reporting also on the security thereof. A "proces verbal" will be made out on every case, and transmitted to the Governor, who will order any precautions that may be necessary, and fix a time within which the work is to be executed by the proprietor or at his expense.

ARTICLE 101.

An extract of the register mentioned in Article 96, indicating the name of the retiring proprietor, and the nature and situation of the mine, is to be published in the places and manner prescribed by Article 43.

ARTICLE 102.

Within one month after the publication, the Governor will send to the Minister of Public Works, the register of the renunciation, accompanied by his opinion thereon, and that of the Government Engineer.

ARTICLE 103.

Should there be any opposition offered by any parties, the Minister will suspend his decision until the case has been decided by a competent tribunal.

ARTICLE 104.

If there is no opposition, or no result from it, the renunciation will be accepted by a Royal Decree, after the matter has been heard by the Council of Mines and the Council of State.

ARTICLE 105.

From the date of the acceptation of his renunciation the retiring proprietor will be free from all obligations imposed by the concession except such as may include the rights of a third party.

ARTICLE 106.

The Royal Decree issued under Article 104 is to be entered in the register of the Office of Mortgages, as provided by the civil law in the

case of transfer of property, and extracts therefrom are to be inserted in the official journals of the province and kingdom.

ARTICLE 107.

If after these formalities are completed, no claims are made against the estate on account of mortgages, within the time fixed by the law for them to be cleared up, then the office will issue a certificate to that effect, and the mine is then free to receive a new concession.

ARTICLE 108.

If on the contrary any claims are proved against the estate, the creditors may obtain a judgment for a sale in the Tribunal of the Circondario, always observing the conditions and obligations imposed by the concession, by the present law, and by the civil law.

ARTICLE 109.

The proceeds of the sale, after deducting all taxes and payments due by the old Concessionnaire to the State, and the legal expenses of the auction, are to be divided amongst the creditors, as the civil law directs.

ARTICLE 110.

Should no purchaser be found for the mine, the Tribunal will pronounce sentence, declaring the mine to fall, without any liabilities, into the possession of the Government, and this sentence after the expiration of the time allowed for appeal to the Court of Cassation against the sentence, will place the mine in the position provided for by Article 107, excepting only the rights of creditors over certain parts of the property, as per Article 116.

The sentence of the Tribunal must be notified to the Minister of Public Works, and entered in the registers of the Office of Mortgages.

ARTICLE 111.

On the Abandonment of a Mine by Ceasing to Work it.

In case a mine is found abandoned, or that no work has been done in it for more than two years, then the Minister of Public Works, on the advice of the Council of Mines, may suspend the concession by issuing a Decree in the same manner as prescribed for injunctions.

ARTICLE 112.

Whenever this injunction remains without effect, the Government Engineer will report on the circumstances by means of a "proces verbal," when the Minister of Public Works will revoke the concession.

The Decree revoking the concession is to be published as provided in Article 43.

ARTICLE 113.

A time of thirty days will be allowed for the parties interested to appeal to the Council of State against the Decree of the Minister.

ARTICLE 114.

The Decree of the Minister, or the decision of the Council of State, revoking the concession is to be notified as provided for by Article 106.

ARTICLE 115.

During the time fixed for clearing up liabilities, the mine will be sold by auction according to law.

ARTICLE 116.

After the sale has taken place, if there be found a purchaser or not, the Articles 109 and 110 will come into force, as in the case of a mine voluntarily abandoned, but the Concessionnaire, who will be declared to have no further rights to the mine, will have a right to remove such property as horses, machinery, &c., that may be considered of no further use in working the mine, provided such removal does no damage to the property. The right is reserved to the Administration to retain, at an estimated price, any property which they may consider necessary.

In every case the property must first pay the taxes, and obligations, due from the date of expropriation.

ARTICLE 117.

Ultimate Lapse of the Concession.

If within two years from the time of the action of Articles 110 and 116, the mine is not worked, sold, or reconcessioned, but still remains in the hands of the Government, then the land comprised within its limits will become free of every obligation resulting from the concession.

ARTICLE 118.

Dispositions referring to existing Interests at the time of passing the present Law.

Any person having a right of proprietorship to any mine at the time of passing the present Act, must, within two years, send to the Governor of the Province a statement of his name and residence, the nature and situation of the mine, and the title of his right thereto; and this statement must be accompanied by the original, or an authorized copy, of his title deeds.

Any person not conforming with this regulation, will forfeit all right to any mining property he may be possessed of. This regulation is not applicable to concessions made by Royal Letters Patent, or to concessions made by Royal Edict of June 30th, 1840.

ARTICLE 119.

All proprietors coming under the preceding Article whose properties exceed the limit of 400 hectares, must, within two years from the time of passing the present law, bring their limits within that scope, or divide the property into several concessions. And within that time they must send in the statement required by Article 118, accompanied by a plan of their workings on a scale of 1 to 500, and also a plan of the surface land on a scale of not less than 1 to 4000, on which the proposed limits of the concession or concessions are distinctly shown.

Any person not conforming to the above regulation will be proceeded against as per Article 55, and the mine will be considered abandoned as per Articles 111 to 117.

ARTICLE 120.

The statement required by Articles 118 and 119 will be registered and its receipt notified to the sender.

The Governor to whom these statements have been sent, will take the opinion of the Engineer of the district, and then forward the complete case to the Minister of Public Works, who on the advice of the Council of Mines will pronounce the relative Decrees.

ARTICLE 121.

In case the title of ownership of the mine shall be found not valid, the Minister of Public Works shall by his Decree declare that such is the case.

This Decree will be intimated to the proprietor in the form prescribed for citations, and within thirty days from the intimation, he must defend his cause before the Council of State.

ARTICLE 122.

If any mines worked by the proprietors, coming under Articles 118 and 119, are found to be in the condition contemplated by Article 73 of the present law, and it is found impossible to fix the limits of the mine, or in any other way to provide for proper working, and security of the works and persons, then Article 73 shall come into force.

ARTICLE 123.

Up to the time of settling the definite limits of the concession, the fixed tax to be paid by the proprietor, as per Article 60, will be the minimum allowed by that Article. Whenever, therefore, the workings shall exceed 400 hectares, the tax will be determined on the basis of that measurement.

ARTICLE 124.

The Concessionnaires existing previous to the passing of the present law, and found to be legally in possession, will be subject to the payment of the fixed and proportional taxes, as per Articles 60 and 61.

ARTICLE 125.

In case the concession of a mine is subject to any ancient feudal rights, the payment of the proportional tax will be made by the Concessionnaire, as required by such rights.

ARTICLE 126.

Special Regulation for the Province of Lombardy.

Existing rights to search for and work minerals, are to continue and have effect until their expiration, but are to be subject to the regulations of this Act, and the holders are within two months of the passing of this Act to furnish a copy of their rights to the Government Engineer of the district.

ARTICLE 127.

Those persons who, before the annexation of the province of Lombardy to the kingdom of Italy, have presented to the Austrian Government demands for permission to open mines, may if their demands are made in conformity with the "Legge Montanistico" of March 23rd, 1854, obtain concessions of the same mines on presenting their demand in conformity with the present law.

ARTICLE 128.

All those who on the passing of this law are found in possession of mines by virtue of a royal concession or of any equivalent right, will for the future hold them under the conditions imposed by the present law.

ARTICLE 129.

All existing rights are maintained in conformity with the sixth chapter of the "Legge Montanistico."

No alteration is to be made in any of the conditions existing at the time of passing the present law.

All holders of rights must send to the Governor of the Province copies of their rights within six months.

REGULATIONS REGARDING MINERALS COMPRISED IN CLASS II.

ARTICLE 130.

No diggings for peat, quarries, or any workings for substances comprised in Class II. of Article 13 may be worked, except by the consent of the proprietor of the surface land.

ARTICLE 131.

Any person wishing to open works of this description, must send to the Intendente of the Circondario, a declaration stating his name

and residence, which residence must be in the Circondario, also the nature of the substance he intends to work, and the method of working which he intends to follow.

ARTICLE 132.

The contravention of the preceding Article will subject the offender to a fine of from 5 to 50 francs.

ARTICLE 133.

Peat Diggings.

The Intendente will, with the assistance of the Government District Engineer, determine the conditions under which peat may be worked, having regard to local circumstances and to the public health and security; these conditions will be communicated to the parties interested by the Syndac of the commune in which the work is situated.

ARTICLE 134.

Persons not conforming to the orders of the Intendente will be liable to have their works stopped, but may appeal to the Minister of Public Works and the Council of Mines.

ARTICLE 135.

Whenever the vicinity of several peat workings render necessary any workings in the interest of public health or security, then the regulations contained in Articles 75, 76, and 77 of the present law will come into force.

ARTICLE 136.

Drainage works may in certain cases be declared works of public utility, and be regulated by the laws relating thereto.

ARTICLE 137.

Quarries.

Whenever in working a quarry it may be desired to make any subterranean workings, then the declaration required by Article 131 must be accompanied by a plan of the ground. This plan must be correctly made and signed by some competent person, it must be on a scale of 1 to 500, and must show all roads, rivers, watercourses, houses, and walls existing within a distance of 500 metres from the proposed workings.

ARTICLE 138.

The proprietors must each year in the month of January present to the Government Engineer a statement of all underground work done in the preceding year, and under special circumstances the Intendente may order this statement to be accompanied by a plan of the work done.

ARTICLE 139.

Open quarry workings are not to be made within 20 metres of any public road, house, or place surrounded by walls, or within 50 metres of any canal, watercourse, or mineral spring.

ARTICLE 140.

The Government Engineer will give to the proprietors any instructions which may be necessary for proper security of the works, and these instructions will be made obligatory by a Decree of the Intendente.

ARTICLE 141.

The Intendente may, on the report of the Government Engineer, and the opinion of the Syndac, after having heard the proprietors, issue any necessary regulations for the working and also stop any dangerous work, the parties interested having the right of appeal to the Governor of the Province.

In case of immediate danger the Syndac may give the necessary instructions, reporting immediately to the Intendente. The cost of all works ordered by the authorities on behalf of public security must be defrayed by the proprietors of the quarries in question.

ARTICLE 142.

In case of any accident occuring in the workings, the regulations contained in Articles 89 to 95 of the present law will come into force.

ARTICLE 143.

The proprietors must at all times allow the Government Engineer or any properly authorized agent of the Government to inspect the works, who in case of refusal may call the police to their assistance.

ARTICLE 144.

Landed proprietors excavating material for their own use are not subject to the dispositions of this Act.

ARTICLE 145.

The preceding Article is also extended to those searching for gold or other metals in the beds, or deposits of rivers and torrents, which search is regulated by the laws regarding the several waters and streams.

ARTICLE 146.

The infraction of Articles 138, 139, and 143 will be punished by a fine of from 5 to 50 francs.

ARTICLE 147.

On the Establishment of Works for the Preparation of Minerals.

The following works are not allowed to be established without the permission of the Governor of the Province :—

Works for the grinding, washing, or other mechanical preparation of minerals.

Works in which, by fire or other agency, minerals of the first class are reduced into metals or other products.

All works in which the preparation of minerals and metals of any kind is carried on, which may in any way become dangerous or injurious to public health or security.

The establishments comprised in this Article are enumerated in Table B, but this may be altered by Royal Decree as may be required.

The contravention of this Article will be punished by a fine of from 50 to 500 francs.

ARTICLE 148.

The demand for permission to establish these works is to be made to the Intendente of the Circondario, and is to state—

The name of the person asking for the permission and his residence, which is to be in the Circondario;

The nature of the works intended to be established and of the substances to be used therein, the method of works to be followed, the number of furnaces and other works to be established, and the time of year at which they will be at work;

The place in which the works are to be established, and what watercourses, if any, are to be used.

The demand is to be accompanied by a plan of the whole works, and designs of the apparatus to be employed.

General plans are to be made to a scale of 1 to 500, and special drawings to a scale of 1 to 100.

ARTICLE 149.

The Intendente will cause the demand to be registered as prescribed by Article 44, and to be published for two consecutive weeks at the door of the office of the Circondario, and in the commune wherein the proposed works will be situated.

ARTICLE 150.

Opposition to the establishment of the works will be received at the office for thirty days after the publication of the demand, and due notice will be given to the parties presenting the demand to appear in support of their case.

ARTICLE 151.

At the expiration of the time given for the opposition, the Intendente will consult with the Municipal Council, with the Engineer of the "Genio Civile," and with the Government Inspector of Forests, after which he will forward all papers relating to the case to the Government Engineer of Mines of the district, who, after taking all means to verify the case, will give his opinion on it, also on the opposition made, and on the conditions which should be imposed on giving the permission.

ARTICLE 152.

The Intendente will then send the whole case, with his opinion thereon, to the Governor of the Province, who will give the permission by a Decree, which will state all the conditions attached to the permission.

ARTICLE 153.

The permission must be published, at the expense of those who have obtained it, at the places and in the manner prescribed in Article 149.

ARTICLE 154.

In case it may be necessary, in the opinion of the Government Engineer and authorities, to make ponds or banks for purifying the water emitted from the works, or condensing chambers for the smoke and gases, then the proprietor is obliged to conform to the directions issued by the Administration on the subject.

ARTICLE 155.

If the proprietor desires to make any alterations in his works, he must, before doing so, send the designs to be approved of by the Intendente.

ARTICLE 156.

If within two years from the date of the permission the construction of the works is not commenced, or if they are at any time left unoccupied for three years, the Government will fix a time for their construction, or the recommencement of work, and if this order is not complied with the permission will be revoked.

The revocation of the permission, or the voluntary renunciation thereof by the proprietor, must be published as prescribed by Article 149.

ARTICLE 157.

Appeal to the Minister of Public Works is always allowable against the decision of the Provincial Governor.

ARTICLE 158.

Works for the establishment of which a simple Declaration is necessary.

Temporary furnaces for burning lime, or works for the preparation of those substances not comprised in Article 147, may be established on making a declaration to the Syndac of the commune in which they will be situated.

ARTICLE 159.

The declaration must give the name and address of the person making it, and describe the nature of the works which he proposes to establish.

ARTICLE 160.

The proprietors of all works will be obliged to conform to all regulations which in the interest of public health and security are issued by the competent authorities.

Contravention of this Article will be punished by a fine of from 50 to 300 francs.

ARTICLE 161.

Various Regulations.

The proprietors of all works must at all times give every facility to the Government Engineer for inspecting the same.

ARTICLE 162.

The proprietors of works coming under the heads mentioned in Article 147 which are in existence at the time of passing the present law are not required to obtain a regular permission, but must make a declaration to the Intendente of the Circondario, which must contain all that is required by Article 148, excepting only that it need not be accompanied by the plans and designs.

A certificate that this declaration has been made will take the place of the permission.

ARTICLE 163.

The proprietors of works mentioned in the preceding Article are also required to make the declaration to the Syndac of the commune as required by Article 159.

These declarations must be made within six months of the passing of the present law.

ARTICLE 164.

Thus works of every kind will in one way or another come under the jurisdiction of this Act.

ARTICLE 165.

The infraction of Articles 155, 158, 161, 162, and 163 will be punished by a fine of from 5 to 50 francs.

ARTICLE 166.

Jurisdiction of Law Courts, and Judicial Proceedings under this Act.

All questions arising regarding the effect and execution of the decrees of permissions of exploration, the concessions of mines, and the permissions for establishment of works, will be regarded as a matter between the Administration and the Permissionnaire, Concessionnaire, or others interested, and will come under the jurisdiction of the "Contenzioso Amministrativo," subject in the case of special laws to an appeal to the Council of State.

Questions arising between the Concessionnaire or Permissionnaire and a third party will be decided by the ordinary civil tribunals.

Article 167.

The "Contenzioso Amministrativo" has special jurisdiction over the infraction of Articles 27, 28, 32, 33, 34, 55, 66, 67, 90, 93, 95, 99, 119, 132, 146, 147, 154, 160, and 165 of the present law.

Matters relating to the infraction of other Articles are under the jurisdiction of the ordinary tribunals.

Article 168.

Non-payment of fines imposed under the present law may be punished by imprisonment, as provided in the general penal laws.

A sentence may be pronounced of both fine and imprisonment.

Article 169.

The application of the present law will in no case prejudice any action taken under the civil law, or under any local regulations.

Article 170.

In the instructions and proceedings under the present law the procedure of the various jurisdictions is to be observed.

Article 171.

The Royal Edict of June 30th, 1840, is repealed, as also are all other laws and regulations contrary to this present law.

We order that the present law, sealed with the seal of State, be inserted in the Government Code to be observed.

Given at Turin,

This 20th day of November, 1859,

Vittorio Emanuele.

Table A.

Mineralogical Districts as mentioned in Article 2.

1. Bergamo,	comprising	the provinces of	Bergamo and Sondrio.
2. Brescia,	,,	,,	Brescia and Cremona.
3. Cagliari,	,,	,,	Cagliari and Sassari.
4. Genoa,	,,	,,	Genoa.
5. Milan,	,,	,,	Milan, Pavia, and Como.
6. Novara,	,,	,,	Novara and Alessandria.
7. Turin,	,,	,,	Turin and Cuneo.

Table B.

Works coming under the Dispositions of Article 147.

1. All works in which minerals are crushed, washed, or otherwise treated for the removal of useless matter.
2. Mills for the preparation of gold and silver.

3. Furnaces for calcining or melting the minerals of the first class.
4. Furnaces for smelting the minerals of the first class.
5. Works in which the minerals of the first class are treated by water.
6. Works for the manufacture of wrought iron and steel.
7. Works for the cupellation of lead, manufacture of oxide of lead and zinc, refining of copper, and refining, by means of acids, of silver and gold.
8. Works for the manufacture of sulphuric, nitric, hydrochloric, and other acids, chloride of lime, sulphates of iron, copper, and zinc, carbonate and sulphate of soda, sal-ammoniac, and all substances containing arsenic and mercury in any form.
9. All works in which coal is reduced into its products, or in which combustible material is manufactured.
10. Works for the manufacture of porcelain and earthenware, and permanent works for the manufacture of bricks, tiles, and cement.

Circular of January 30, 1861, *on the Taxes on Mines and Payments to the Government required by Law.*

The law of November 20th, 1859, No. 3755, requires from all Concessionnaires of mines the payment of two annual rates: A fixed rate of fifty centimes on each superficial hectare of land included in the concession, which rate must in no case be less than 20 francs per annum; and a proportional rate of five per cent. of the nett profit of the mine, which may for convenience be commuted into another fixed annual payment.

Under the present law the Concessionnaires are released from payment of the tax imposed by the law of June 30th, 1840, so that the instructions contained in the Circular of the Minister of Public Works dated December 31st, 1854, are not applicable to the collection of the new taxes.

With a view, therefore, to avoid mistakes, and to fix a uniform rule for all those parts of the kingdom where the new law is in force, the following regulations are issued.

The Fixed Tax. See Articles 59, 60, 123, 124, *and* 128.

The fixed tax of 50 centimes per hectare included in the concession is due from every Concessionnaire in possession of a mine, whether the concession was granted prior to the time of the laws passing or no. This tax offers no difficulty in its determination.

The Proportional Tax. See Articles 59, 61, 62, 63, 64, 66, 124, 125, *and* 128.

The proportional tax of 5 per cent. of the nett product of the mine is equally due from all Concessionnaires and legal holders of mines which are not on property subject to feudal rights, excepting only

those whose title deeds hold them exempt from any dues. This tax may, according to Article 62 of the present law, be commuted into a fixed annual payment.

On estimating the Value of the Proportional Tax.

The nett produce of a mine is the difference between the selling price of the mineral, on the mine or at some other determined place, and the expenses incurred in obtaining that produce in that state and in that place.

The particulars on which such valuation is founded will be ascertained from the books and reports kept in compliance with Article 64 of the law. The expenses to be taken into account are those only which are actually incurred in extracting the mineral, such as labour, depreciation and consumption of plant and material, construction and repair of roads for the transport of mineral, expenses of ventilating and drainage; also deductions may be made on account of expenses incurred in the original search and opening of the mine under the permission of exploration, and lastly the expenses of management and administration incurred on the spot.

The expenses which, according to Article 61, are not to be taken into account in determining these deductions, are those incurred in the general management of the concern in other places than on the mine and in financing the undertaking; also interest on capital is not to be taken into account.

On the Reports of Deliveries required by Law.

The reports respecting the taxes are required simultaneously with the mineral statistics, and are to be inserted in the schedules provided by the Administration for that purpose.

During the month of November in each year the District Engineers will transmit to the Intendente of the Circondario a statement of the taxable mineral in their several districts, accompanied by as many delivery schedules as there are mines therein, regularly headed to each proprietor.

The Intendente of the Circondario will take care that before the end of the following month of December the respective schedules be sent through the Syndacs of the communes to the various proprietors at their stated residences, so that they may within the time prescribed by law deliver, along with the other data, the necessary extracts from the accounts required by Article 64 of the law.

The Concessionnaires will be required to fill in correctly the forms furnished them, and to transmit the same to the Syndacs within the month of January following, as provided by Articles 64 and 66 of the law.

The Syndacs are required to see that these reports are duly sent in, and to forward them to the Intendente of the Circondario within the first ten days of February. The Syndacs are required, when forward-

ing these reports, to inform the Intendente in case they may have reason to suspect any of them of being incorrect.

The delivery reports will be forwarded to the Mining Engineer of the district for verification, and from them he will proceed to form his proposal for assessing the tax.

The Tax Roll is to be completed by the first day of March and sent to the office of the Intendente, accompanied by any observations that the Engineer may wish to make, and a statement of any inaccuracies which he may have found in the reports sent in by the Concessionnaires.

On receipt of these Tax Rolls the Intendente will cause a notice thereof to be published at the chief town of the district, and in the various communes wherein the mines are situated, in order that within eight days the Concessionnaires may present any objections which they may desire to make, should they consider themselves taxed beyond the provisions of the law. At the expiration of eight days from the publication, the Roll is to be sent, in three copies, to the office of the Governor of the Province, along with any objections which may have been made.

The Governor of the Province will, after having heard the opinion of the Government Engineer of the district, and if necessary also taken that of the Council of Mines, determine the taxes to be paid, marking the same in the proper columns of the three copies of the Tax Roll, and attaching also to each copy a copy of the Decree establishing the amount.

The three copies of the Tax Roll, with all papers relating thereto, will then be forwarded by the Provincial Governor to the Minister of Agriculture, Industry, and Commerce, who after due inspection, and rectification if necessary, will send one copy to the Finance Department for collection of the tax, another to the office of the Provincial Governor, and the third, accompanied by all the other papers, he will return to the Government Engineer of the district, to enable him to make out the necessary mineralogical statistics.

On Converting the Proportional Tax into a Fixed Annual Payment.

The amount of the yearly payment, into which the proportional tax may be converted, may, if circumstances permit, be determined on the basis of the average tax which has been paid for several successive years. In the case of mines commencing work it may be determined on the prospective yield and expenses, but in this case the conversion is not to be made for a period exceeding five years.

To obtain this conversion the Concessionnaire or his representative must make a request, on stamped paper, to the Intendente of the district, stating the length of time for which he wishes the conversion to be made, and the fixed annual sum it is proposed to substitute for it. It must also be accompanied by a statement of the receipts and expenses of the last five years, if the mine has been so long working.

The Intendente will, on receiving the application, confer with the Government Engineer, and then forward the application, with their opinion thereon, to the Governor of the Province, who will transmit the whole case to the Minister of Agriculture, Industry, and Commerce. The Minister will lay the matter before the Council of Mines, and if they pass it, will then forward it to the Finance Department, in order that the necessary contract may be concluded between the Minister of Finance and the Concessionnaire of the mine.

On Reconverting the Annual Payment into the Proportional Tax.

An application for converting the annual payment into a proportional tax must be made in the same manner as in the case of the conversion of the tax into an annual payment. The statement of receipts and expenses is to be verified by the Government Engineer of the district.

On Keeping Accounts of Receipts and Expenses.

The accounts required by Article 64 of the law must be carefully attended to by the owners of the mine, and also rigorously supervised by the Government Engineer. It is proposed not to assign any particular form in which these accounts are to be kept, but care must be taken that they be properly signed and authenticated on each sheet, and that they comprise a statement of the weights or measurements of all mineral extracted with its approximate value. The accounts of expenses should also show all payments made under the heads of wages, contract labour, material, depreciation of plant, working expenses of machinery, maintenance of roads and buildings, administration, and office expenses.

On Neglecting to Furnish Returns, or Sending in False Ones.

Should the Concessionnaire or his agent, to whom due notice has been given, neglect to furnish the returns, or should there be reason to believe that those furnished are untrue, the Intendente will through the local authorities give notice to the Concessionnaire that the fines provided for by law will be enforced, and should the Concessionnaire still refuse to furnish such returns, or furnish such as are manifestly false, the Intendente will instruct the Government Engineer with the local authorities to visit the mine and make out the necessary returns from what information he can gather, at the same time proceeding against the Concessionnaire as the law directs.

(Signed) The Minister of Public Works,

T. Corsi.

DISCUSSION.

Mr. E. H. Walker (H.B.M. Consul, Pernambuco) said it was some years since he left the island of Sardinia, where he had had the honour of representing Her Majesty's Government for about eight years. During that period he occasionally accompanied Mr. Alford in some of his expeditions. Everything which the author had expressed about the island was strictly true. The island of Sardinia required her internal resources to be better known. Roads were wanted; and he was afraid that the unknown wealth of the island must be hidden until the Italian Government or some foreign capitalists could expend money in developing the same. The residents in the island had to contend with malaria, and the whole of the mining operations had to be suspended from St. Giovanni's Day, which was the 24th of June, until the rainy season commenced in October. That suspension was, of course, very injurious to large capitalists, for they had to keep their engineers away from the island on the main land for about six months of the year. The mines must always be kept working to a certain extent, otherwise the concessions would be lost, and therefore a few miners were left on the spot; but to all intents and purposes the real work ceased during the interval which he had mentioned. With regard to the produce of the island, the following tabulated statement would show the amount of mineral ore produced during the mining campaign of 1876–77 in comparison with that of the years 1875–76 :—

Quality of mineral produced.	Campaign 1875–76.	Campaign 1876–77.	
	Value.	Quantity.	Value.
	Francs.	Tons.	Francs.
Argentiferous lead ore	8,883,086	36,028	11,017,279
Crude and calcined calamine and blend	4,164,603	81,667	4,310,344
Antimonium	—	150	45,000
Manganese	80,000	3000	105,000
Nickel, cobalt, and bismuth	6,000	250	250,000
Iron	150,046	13,300	146,300
Lignite and anthracite	107,256	11,345	180,875
Total ..	13,390,991		16,054,800
Increase in campaign 1876–77			2,663,809

Mr. F. E. Duckham said that the author had stated in his paper that the value of Sardinian coal was only 60 per cent. of that of English coal. The table of comparative values which accompanied the paper did not show such a great difference either as regarded the heating power of the Sardinian coal or its lower specific gravity, and consequent greater bulk for stowage.

Mr. Charles Horsley asked what the quality of the Sardinian iron was. He should also like to know why Mr. Alford did not go down 600 feet in boring for coal, instead of only 300. There was coal on the north, the north-east, the south, and the south-east of the spot at which the boring was made, and there was a valley between those points; and therefore it appeared to him (Mr. Horsley) that the engineers who went out had a very good reason for supposing there would be coal in the valley. In many coal countries the coal would be found to dip and go down very rapidly indeed under such circumstances. That was the case in England. It did not follow that because no coal was found at 300 feet there would be none at 600 feet. It was a question whether there was not really coal in the basin at which the boring was made. It was only 65 feet to the 4 feet seam. A little fault might put the coal down lower than 300 feet. The country seemed to be a very rich one; it would be a very good thing if coal could be obtained there, so that our best coal could be kept for use in England. He would be glad to know if labour was cheap in the island.

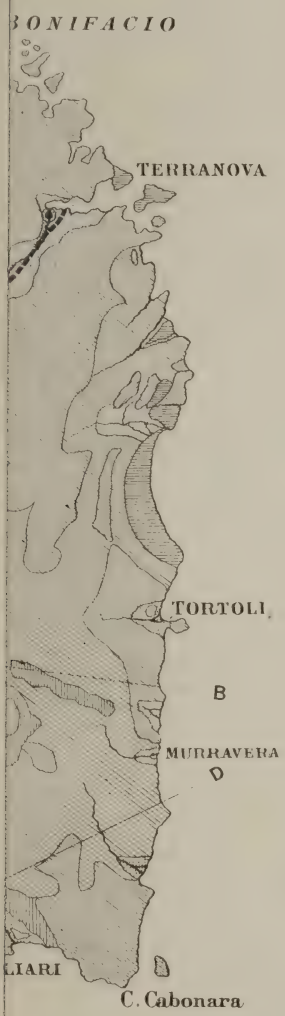
The President said it was quite refreshing to hear an English ironmaster asking about the quality of Sardinian iron. It seemed as if a fear had crept over Mr. Horsley that the Sardinian iron might be equal to the Derbyshire iron. He (the President) might remark that Sardinia was not the only rich country which remained poor for want of facilities. In Sardinia and in Spain there were rich mineral deposits, which might be worth an immense amount of money if they could be properly worked. The difficulties of transport were felt in Sardinia, and from what he had read of Spain, he rather thought that was the case there also. Then the laws of Sardinia interfered with progress. Anything which interfered with the liberal application of capital would prevent the fructification or the development of any industry. That was the result of the strikes which we had had in our own country, and which had in some degree extended to other places. The most recent development of the mischief of strikes was now being felt in the quiet country of Sweden, amongst the woodcutters. Wood-cutting was the principal industry of that country. The effect of all such causes was

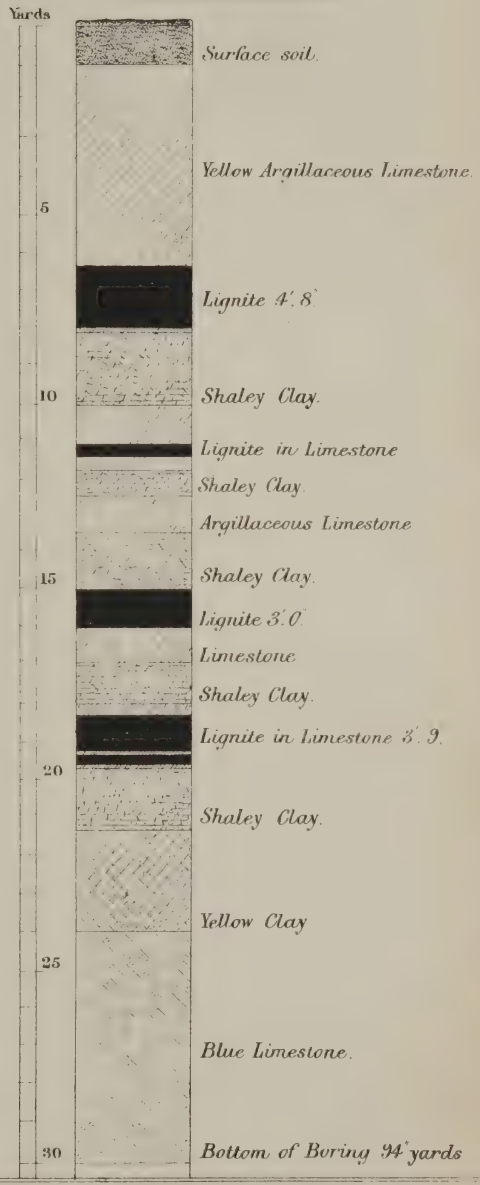
to disturb trade and to check the application of capital by causing timidity on the part of capitalists. Wherever there was a want of confidence amongst capitalists, there would be a comparative cessation of profitable enterprise. It appeared that one thing which was wanted in Sardinia, in order to bring about the development of the rich treasures buried in the earth and ready to the hand of man, was convenient laws which would induce the application of capital. If such laws were introduced the rest would follow, and the difficulty of transport would be overcome. The world was the poorer for being kept without the supplies of minerals which Sardinia could afford, and therefore all the world was interested in the progress of the island.

Mr. C. J. Alford, in reply to questions, explained that the 60 per cent. value of Sardinian coal compared with English coal stated in his paper was the comparison of the money value as a marketable article, representing only the practical value under the disadvantageous circumstances under which it had generally been tried. On the other hand, laboratory experiments gave results which could scarcely be expected to be realized in practice, so that the true practical value would lie somewhere between the two. Regarding the quality of the iron produced from Sardinian ores he could not speak, as he had never seen any of it. It was smelted mostly in the neighbourhood of Marseilles. He did not think it was used alone, as it contained a large proportion of silica and phosphorus. That was the magnetic iron ore from the San Leone Mine. There was also a large quantity of ironstone and hematite in the island, containing at least 50 or 60 per cent. of iron, which ought to find a market. The reason for not carrying the borings deeper in the coal exploration was that the crystalline limestone of Silurian origin was undoubtedly reached, and under that no coal could possibly exist. Regarding the labour to be obtained in the island, the Sardes were not of much use; their wages were from 1 franc to 2 francs per day, and they did very little work for it. After a time they improved slightly, but he knew of few cases in which a Sarde had turned out a really good workman at mining or anything else. All skilled labour had to be imported from the Continent, mostly from the neighbourhood of Lucca, in Tuscany, and from Piedmont. Those men were some of them first-rate miners; their wages were from 2 to 5 francs per day. They had their regular routine for the year; they could come over to the island in October and work until the 24th of June, St. Giovanni's Day, and then they all went back to their homes on the Continent again to look after their vines and corn, which during the winter were left in charge of the women and

children. There was fine country in the island, and land was very cheap. If the Government would give the people some encouragement and not drive them to desperation by taxation which they were unable to bear, those people with their families might be induced to go and settle there instead of going away to the Brazils and Algeria as they now did by thousands. The fever prevalent in Sardinia during the summer months was undoubtedly a drawback, but it soon disappeared before cultivation.

SECTION OF THE CONNESA COAL BASIN at the BARBUSI MINE.



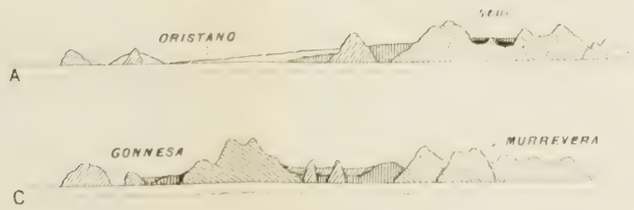


GEOLOGICAL MAP
of the Island of
SARDINIA.

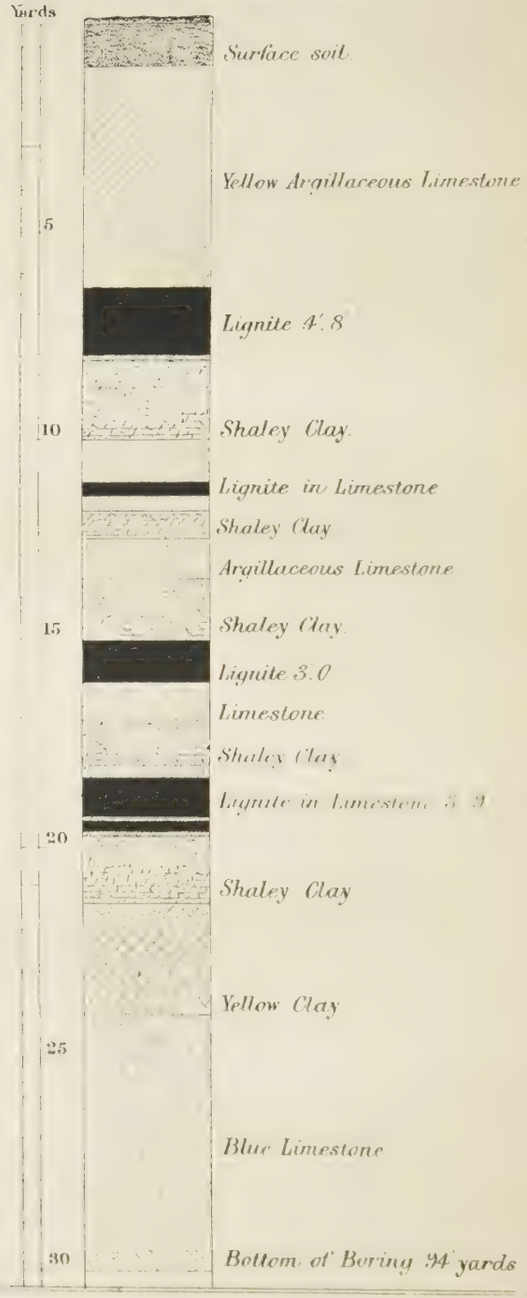
Scale — 1 — 1500000.

- *Alluvium, and Recent*
- *Tertiary formation. Heavy blue and yellow Clays, alternating with Argillaceous Limestone and beds of Coal*
- *Coarse Shelly Limestone with calcareous Sandstone and Clay.*
- *Silurian Limestones, and Clays, Crystaline Schists, with Porpheretic dykes and Metaliferous veins.*
- *Trachyte and Basalt.*
- *Granite, with Porpheretic dykes, and veins of quartz and barytine, with argentiferous galena, and iron ores.*

SECTIONS.



SECTION OF THE CONNESA COAL BASIN
at the
BARBUSI MINE.



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THE VACATION VISITS.

During the vacation of 1879, four visits were made to engineering and other establishments of interest to the members. The first visit took place on the 24th of June, and was made to the Providence Ironworks, Millwall, and the Millwall Docks. The members were conducted over the ironworks by the proprietors, Messrs. Cutler, and were afforded the opportunity of seeing some large gas-holders and other gasworks appliances in course of construction, as well as kindred engineering works. The members were conducted over the Millwall Docks by Mr. F. E. Duckham, who explained the general arrangement and working appliances of that undertaking, including the new grain machinery, Mr. Duckham's pneumatic discharging dredger, the dry dock and pumping engines, the hydraulic engines, and general machinery. Messrs. Cutler and Mr. Duckham entertained the visitors at luncheon during the day, and the visit concluded by an inspection of the ironclad corvette 'Orion,' which was being fitted out by Messrs. Samuda Bros. in the Millwall Docks.

The second visit was made on the 30th of July, to the Telegraph Cable Works of Messrs. Siemens Bros. at Charlton, over which the members were conducted by Dr. C. W. Siemens in person. The visitors there were afforded the opportunity of inspecting the various processes connected with the preparation of the materials used in the manufacture of telegraph cables, and the manufacture of the cables themselves, as well as that of various kinds of electric telegraph apparatus and instruments. The department for the production of magneto-electric machines and apparatus was likewise inspected, as was also the telegraph cable ship 'Faraday,' on board of which Dr. Siemens entertained his guests at luncheon.

The third visit took place on the 26th of August, when the Works of the Victoria Dock Extension were for a fourth time inspected by the members. A general description of these works appeared in the Transactions for last year, and need not here be repeated. They comprise a large addition to the dock accommodation hitherto afforded by the London and St. Katharine Dock Company, and have entailed in their execution some very

heavy engineering works, principally in excavations for some 80 acres of additional water area, in building the extensive length of dock walls in concrete and in forming a tunnel under the floor of the dock for the accommodation of the North Woolwich branch of the Great Eastern Railway, which formerly crossed at the level of the dock surface. The members were conducted over the works by Mr. C. Andros (on behalf of Mr. A. M. Rendel, the engineer of the docks) and Mr. W. Colson, the engineer of Messrs. Lucas and Aird, the contractors, who entertained the visitors at luncheon.

The fourth and last visit of the vacation was made to the works of Messrs. A. H. Bateman and Co., at Greenwich, where the Members inspected the various processes connected with the manufacture of silicate stone, as well as those connected with the manufacture of emery grinding and polishing wheels and machinery. They also witnessed the practical application of those wheels by means of machinery in motion. Mr. A. H. Bateman conducted the visitors over his works and entertained them at luncheon during the day.

October 6th, 1879.

ROBERT PAULSON SPICE, PRESIDENT, IN THE CHAIR.

THE STRENGTH OF WROUGHT-IRON RAILWAY AXLES.

By THOMAS ANDREWS.

In introducing the subject of wrought-iron railway axles, the author thinks it may not be uninteresting first briefly to describe the Wortley Ironworks, near Sheffield, on the estate of the Right Hon. the Earl of Wharncliffe, of which the author is the proprietor. These works are about the oldest ironworks in the United Kingdom, and at them some of the first railway axles were made at the commencement of the railway system, and have since continued to be largely manufactured up to the present time. It is interesting to observe that best charcoal iron was largely made at the Wortley Ironworks as far back as, and even earlier than, the year 1660, and the works have been in continuous operation to the present time. They were enlarged and improved in the year 1713, and towards the end of the eighteenth century were worked by Mr. James Cockshutt, a civil engineer and F.R.S., who being then in partnership with Mr. Richard Crawshay, the great ironmaster of South Wales, introduced at the Wortley Ironworks the celebrated "Cort's" process of rolling puddled blooms with grooved rolls. Thus almost simultaneously with the new mill at Cyfarthfa, one of the first rolling mills of this description in the kingdom was put in operation at these works.

A letter from Mr. Cockshutt to Mr. Coningsby Cort—son of Henry Cort—dated Wortley Ironworks, April 17th, 1812, entering into the merits of Henry Cort's invention, forms an interesting historical record concerning this early and valuable development of the iron trade. This letter will be found reproduced in Dr. Percy's 'Metallurgy of Iron and Steel,' page 634.

Dr. Percy thus remarks :—"In an interesting letter of Mr.

Cockshutt, partner of Mr. Richard Crawshay, the merit of the inventions, both of grooved rolls and puddling, is freely accorded to Cort. It is excessively damaging to the memory of Homfray, and is so important in its bearing on the question under consideration, that I present it *in extenso*." The letter reads as follows:—

"WORTLEY IRONWORKS, *April* 17*th*, 1812.

"DEAR SIR,—I had heard, I believe, not less than two or three years before I felt it needful to pay any particular attention to the subject, of the great advantages and the great improvements obtained by your father's practice of rolling iron, in preference to the long-continued and established method of forming bars by the use of forge hammers. But when Mr. Crawshay—then my partner—determined that a trial should be made of your father's method of making iron on the puddling system, I accompanied him to Fontley, when I first saw the practice of forming bars from blooms by the use of grooved rolls, and this, by a reference to my remarks made at the time, and now before me, was in the month of June, 1787, with which I was greatly pleased, and that operation was also determined to be made a part of our trial at Cyfarthfa. Shortly after my return I began to prepare plans and drawings for a more powerful mill for that purpose, with such improvements as occurred to me; and accordingly a mill was constructed on a plan which perhaps has not been much improved since that time, but, I believe, much imitated.

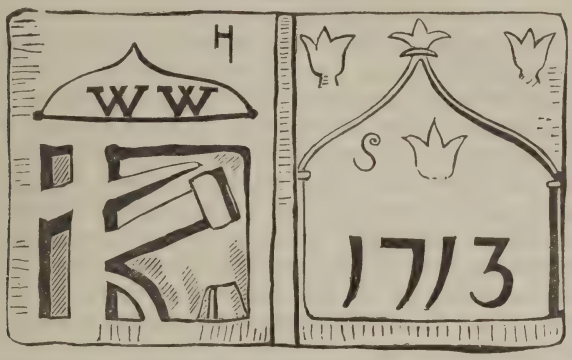
"I have always considered and believed that the merit of rolling bars from blooms was due to your father, as well as that of making iron by the puddling process, both of which Mr. Homfray, who kept an attentive eye over our process, was glad, with my permission, to copy, not only in the construction of his furnaces after the patterns of those erected by your father's workmen, by whom Mr. Homfray was first instructed when he took up the process, and who also borrowed the very patterns made use of by me in the construction of the mill at Cyfarthfa. I must add, if Mr. Crawshay had not been convinced himself of your father's just claims, he would not have consented to pay 10s. per ton for patent right.

(Signed) "JAMES COCKSHUTT."

There are several carved stones on the walls of the old forge, giving the dates of various alterations and improvements, one of the most interesting being a well executed carving of a forge

hammer put down in the year 1713; copy of this carving is here given—

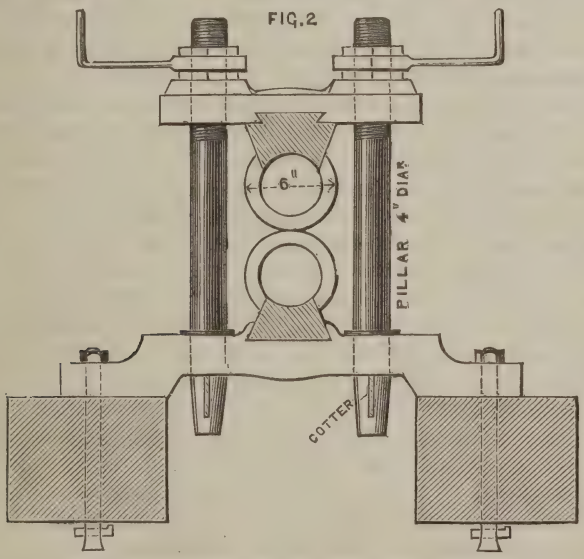
FIG. 1



CARVING OF A HAMMER ERECTED AT WORTLEY IRONWORKS, A.D. 1713. SCULPTURED ON THE FORGE WALL.

David Burkinshaw, a millwright, who was apprenticed as a boy to Mr. James Cockshutt at Wortley Ironworks, and worked above sixty years at these works, dying October 30th, 1868,

FIG. 2



at the age of seventy-two years, remembered as a boy seeing the first grooved rolling mill put down at the tilt mill, Wortley

Ironworks, for rolling iron into rods, instead of the old method of tilting them under the hammer. This mill was about the first, if not the first, of its kind in this part of Yorkshire, erected to carry out practically Mr. Henry Cort's invention of grooved rolls, to the value of which invention Mr. Cockshutt speaks most highly in the letter just before spoken of. This old mill was put down without housings on what was then called the "box and pillar system," and was used for rolling charcoal iron bars from $1\frac{1}{4}$ inch square down to $\frac{3}{8}$ inch diameter for wire-drawing purposes. A large sheet mill on this ancient principle is still to be seen at the works. This rolling mill is driven by two water-wheels of about 18 horse-power each, running reverse ways, without toothed gear of any kind, one driving the top roll, the other the bottom one. The water-wheel is also weighted by a very heavy stone rim, bolted together in segments, so that the wheels act as fly-wheels.

When digging out some foundations during 1868 to about 6 feet to 8 feet below the present level of the ground, there were found amongst a quantity of old black oak beams three ancient cannon-balls, measuring respectively $5\frac{1}{4}$ inches in diameter, and weighing 16 lbs. 15 oz.; $2\frac{3}{4}$ inches in diameter, and weighing 2 lbs. 9 oz.; $2\frac{1}{4}$ inches in diameter, and weighing 1 lb. $3\frac{1}{2}$ oz. These are still in the possession of the author. It is not, therefore, at all improbable that cannon-shot was at some early date manufactured at these old ironworks.

The mode of conveying the iron from the works long before the days of railways was by means of pack-horses over the moors to Manchester, Bradford, Halifax, or other towns. Where turnpike roads were constructed, the mode of conveyance was changed from pack-horses to waggons. Some of these obsolete bridle-paths are still in existence. In those early days parties frequently fetched their own iron away, so that prices were then quoted at the works. The author has often heard David Burkinshaw say that when young he had seen as many as a dozen carts from all parts of Yorkshire within a radius of thirty miles waiting for shovels to be rolled and iron to be tilted for them at the tin-mill and forges. In times of dry weather, when the water was low in the river and dams, these teams and pack-horses had frequently to wait several days before the orders could be executed. This waiting necessitated the erection of stables, which are still standing, but some of them have been recently converted into cottages for workmen.

In the early part of this century a waggon was regularly kept going on the Rotherham and Salterbrook turnpike, baiting at the 'Flouch Inn,' and then passing over the moors, making two

journeys per week to Manchester from Wortley Forges, taking tilted and bar iron there, and loading back with scraps.

The first railway axles were made at Wortley Ironworks about the year 1838. At the commencement of the railway system it was considered a great achievement to make two or three axles per day under the old hammer, and much charcoal iron was used, charcoal being largely employed as the fuel. By way of contrast with this early period in the history of the iron trade, and in illustration of modern progress, it may be stated that these works now possess the necessary capabilities for turning out from 250 to 300 railway axles per week.

The following inscription, on a tombstone in Wortley Churchyard, bears testimony to the great antiquity of these ironworks: "Here lies the body of Francis Askew, of Upper Forge, hammerman; died 24th October, 1669."

The works were again extended in the year 1825, and were further largely increased and thoroughly remodelled in 1855 and in 1868. They now possess every modern facility for the manufacture of best railway axles and all the best classes of wrought scrap iron. Hoping this short digression, owing to its antiquarian interest, will be pardoned, the author will now proceed to the consideration of the subject of this communication and bring under notice a few practical experiments, made in the course of his usual occupation, which amongst many others tend to show the great resistance to sudden strains which best best fagotted scrap axles are capable of exerting. There being considerable diversity of opinion amongst engineers at the present time as to the varying merits and demerits of wrought-iron axles as compared with steel axles for railway purposes, the recording of these experiments may not perhaps be regarded as out of place, and in any case, even as a simple contribution of facts, will not probably be uninteresting to those concerned in the construction of railway rolling stock.

It must be admitted that the question of iron *versus* steel as a material for axles needs approaching with the utmost care, as many arguments may be adduced in favour of either material. Of course in dealing with a question of this nature the pecuniary element has a proper place of its own: but this should not be allowed to exercise undue influence in the consideration of a matter of such primary importance as the public safety on our railways.

It would be unsuitable in a short contribution of this kind to attempt to sum up all the *pros* and *cons* of this great argument, the object being rather to add one more record of observations, showing the great toughness, tenacity, and general behaviour

of best wrought-iron axles when submitted to the most severe sudden strains and blows.

As regards the making of axles, what should be aimed at in the manufacture of wrought-iron axles is great toughness and tenacity of material combined with that necessary amount of hardness needful for the proper and economical wear of the journals; but this hardness ought never to approach brittleness —neither, on the other hand, should the iron be of too soft and fibrous a nature, otherwise there is danger of sudden fracture. It is the due regard to these and other important matters that is essential to the successful manufacture of wrought-iron axles. On the old principle, that in the aggregate the resisting strength of a bundle of iron rods of a given diameter exceeds the resisting strength of one bar of homogeneous iron of the same area, the good old fagotted system of making axles, when properly carried out, is by far the most excellent, reliable, and satisfactory method of constructing them. This is also illustrated by the fact that a bar of precisely the same quality of iron when finished to a smaller size endures more tensile strain than the same quality of iron if finished to a larger size, as shown by the experiments on the opposite page.

The author will next offer a few remarks upon some of the general practical methods of examining and testing railway axles. The following are amongst the tests required for best best axles of iron or steel by some railway companies:—

"The axles are to be tested by a weight of 1 ton falling through a space of 30 feet, the axle resting upon solid iron bearings 4 feet apart. It must receive at least two blows without showing any signs of fracture."

"The axles are to be capable of standing without fracture five blows from a weight of 2000 lbs. falling from a height of 20 feet upon the axle, which shall be placed upon bearings 3 feet 6 inches apart, and shall be turned after each blow."

"The axles to be placed upon supports 3 feet 6 inches apart, and to stand a weight of 1800 lbs. falling a distance of 19 feet."

"The axle to be placed upon supports 3 feet 6 inches apart, and to stand two blows from a weight of 1 ton falling 20 feet; axle to be turned after each blow."

"The axle to be placed upon supports 3 feet 6 inches apart, and to stand four blows from a weight of 2369 lbs. (21 cwt. 0 qr. 17 lbs.) falling a distance of 17 feet 6 inches on the centre of the axle; the axle to be turned over after each blow."

"The axle to be placed upon supports 3 feet 6 inches apart, and to stand four or five blows from a tup of 2300 lbs. (20 cwt. 2 qrs. 4 lbs.) falling a distance of 18 feet; axle to be turned over after each blow."

TABLE No. 1, SHOWING THE GREATER RESISTANCE TO TENSILE STRAIN OF LESSER SIZES OF BEST BEST IRON WHEN COMPARED WITH LARGER.

Size of iron.	Diameter.	Area.	Elastic stress per square inch.	Ultimate stress per square inch.			Ratio of elastic to ultimate.	Contraction of area at fracture.	Appearance of fracture.
inch.	turned to	sq. in.	lbs.	lbs.	tons.		Per cent.	Per cent.	
½	·357	·100	36,700	61,070	27·26	Average 26·83	60·1	43·0	Fibrous.
,,	,,	,,	36,200	60,130	26·84		60·2	39·0	,,
,,	,,	,,	35,500	59,110	26·38		60·0	34·0	,,
¾	·564	·250	33,600	55,920	24·96	Average 24·58	60·0	42·0	,,
,,	,,	,,	31,400	54,890	24·5		57·2	39·2	,,
,,	,,	,,	32,300	54,445	24·3		59·3	36·4	,,

TABLE No. 2, SHOWING THE QUALITY OF THE IRON FROM WHICH THE AXLES WERE MADE.

Description.	Original.		Ultimate stress.			Fractured.				Stress per sq. in. of fractured area.	Extension.		Appearance of fracture.
	Size.	Area.	Total.	Per square inch of original area.		Size.	Area.	Difference. Area.	Difference. Per cent.		Inch.	Per cent.	
				lbs.	lbs.					lbs.			
in. × 1 in. best	1·00 × ·99	·990	53,410	53,949	52,577 23·5 tons	·86 × ·85	·731	·259	26·1	71,148	2·08	20·8	Fibrous.
				24·1 tons									
,, ,,	1·00 × ·99	·990	52,975	53,510		·89 × ·88	·783	·207	20·9		1·62	16·2	,,
,, ,,	1·00 × ·99	·990	51,780	52,303		·86 × ·85	·731	·259	26·1		1·49	14·9	,,
,, ,,	1·00 × ·99	·990	51,305	51,823		·81 × ·87	·765	·225	22·7		1·43	14·3	,,
,, ,,	1·00 × ·99	·990	50,790	51,303		·81 × ·80	·648	·342	34·5		2·76	27·6	,,
				22·9 tons					26·0			18·7	
1¼ in. × 1¼ in. ..	1·28 × 1·29	1·651	84,780	51,350	51,130 22·8 tons	·92 × ·93	·856	·795	48·1	99,352	3·14	31·4	,,
,, ,,	,,	,,	84,490	51,175		·91 × ·92	·837	·814	49·3		3·38	33·8	,,
,, ,,	,,	,,	83,980	50,866		·92 × ·93	·856	·795	48·1		3·11	31·1	,,
									48·5			32·1	

"The axle to be on bearings 5 feet 11 inches apart, the monkey weighs 8 cwt., and the height of drop begins at 18 feet 9 inches, and is increased by 2 feet at each blow. When the axle has received a set to the extent of about 9½ inches, it is turned over and struck on the opposite side till it has received an equal set in the opposite direction, this process being continued until the axle has sustained an amount of mechanical work, which, estimated by the formula $P \times \sqrt{2g.h}$, amounts to 500,000 foot-pounds."

"The axle to be placed on bearings 5 feet 11 inches apart, a weight of 8 cwt. allowed to fall on centre of axle from a height of 24 feet 6 inches, and the axle to be turned after each blow."

Some engineers prefer the steady application of strong pressure applied to the centre of an axle placed on supports, the pressure being continued, the axle meanwhile deflecting till fracture occurs. Referring to this mode of testing, a best best fagotted scrap axle—of Wortley manufacture—was gradually bent cold, until the two journals met. No fracture being shown in the axle, the two ends were then firmly secured together against the rebound of the elastic force of the iron.

Another axle was treated in the same manner until the two journal ends met within 2 feet 1 inch, as shown in test No. 0.

TEST NO. 0, OF A BEST BEST FAGOTTED SCRAP CARRIAGE AXLE (MARK, "WORTLEY BEST BEST").

	ft.	in.
Total length of axle	7	3½
Length from centre to centre of journals	6	6
Length of wheel seats	0	10⅞
Length of journals	0	7½
Length of end collars	0	1
Diameter of middle	0	4¼
Diameter of wheel seats, full	0	5⅛
Diameter of journals	0	3¾
Diameter of end collars	0	5⅛

Fig. 3 was bent with ten blows from a ball (21 cwt. 0 qr. 17 lbs.) falling 6 feet. Afterwards bent by means of pressure

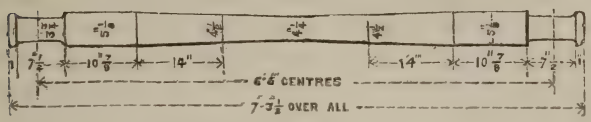
FIG. 3.

FIG. 4.

until the two ends were within 2 feet 1 inch of meeting, giving a deflection of 2 feet 11½ inches, as shown by the sketch, Fig. 4.

The following cut shows a forged sketch of axle:—

FIG. 5.



The axles examined in the following experiments were made at the author's works to meet the requirements of some of the foregoing tests, and were of the brand generally known as "Wortley Best Best Fagotted Scrap," and forged to specifications shown in each test, the axles tested being indiscriminately taken at the various dates from orders on hand at the time. The quality of the iron in the rough used in the manufacture of these axles will be seen on reference to Table No. 2.

Each axle was placed on supports, at distances apart, as shown in following tabulated results, and weights, as shown in tables, allowed to fall on centre of axle, the deflection being carefully noted after each blow. The tests are divided into two kinds, one showing a series of axles submitted to the most severe shocks, the other showing the behaviour of a number of axles when submitted to a large number of lighter blows. These tests show the great toughness and resisting strength of the axles. The results speak sufficiently for themselves.

The tests of axles referred to in the first portion of this paper were, as will be seen from what follows, very numerous and complete. Each tabular statement is accompanied by a dimensioned sketch of the axle.

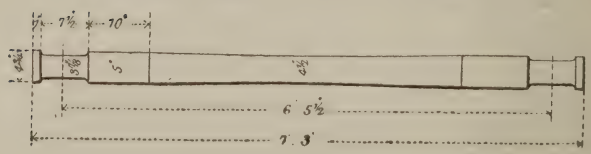
TEST NO. 1, OF A BEST BEST FAGOTTED SCRAP CARRIAGE AXLE (MARK, "WORTLEY BEST BEST"). MAY 1ST, 1876.

Distance between bearings.	Height from which weight of 2369 lbs. falls (21 cwt. 0 qr. 17 lbs.).	Number of blows.	Deflection from end to end.	Deflection between bearings.
ft. in.	ft. in.			
3 6	17 0	1	$9\frac{1}{2}$ in.	$4\frac{1}{4}$ in.
			Turned over.	
3 6	17 0	2	$1\frac{1}{4}$ in. past straight	$\frac{3}{4}$ in. past straight
,,	,,	3	8 in.	$3\frac{1}{2}$ in.
			Turned over.	
3 6	17 0	4	Re-deflected 1 in.	Re-deflected $\frac{3}{4}$ in.
,,	,,	5	8 in.	$3\frac{1}{2}$ in.
			Turned over.	
3 6	17 0	6	Re-deflected $1\frac{1}{4}$ in.	Re-deflected $\frac{3}{4}$ in.
,,	,,	7	$7\frac{3}{4}$ in.	$3\frac{1}{2}$ in.
			Turned over.	
3 6	17 0	8	Re-deflected $1\frac{1}{4}$ in.	Re-deflected $\frac{3}{4}$ in.
,,	,,	9	7 in.	3 in.
			Turned over.	
3 6	17 0	10	Re-deflected 2 in.	Re-deflected $1\frac{1}{4}$ in.
,,	21 9	11	$6\frac{3}{4}$ in.	3 in.
			Turned over.	
3 6	21 9	12	Re-deflected $3\frac{1}{2}$ in.	Re-deflected $1\frac{3}{4}$ in.
,,	,,	13	Broken	

	ft.	in.
Total length of axle	7	3
Length from centre to centre of journals	6	$5\frac{1}{2}$
Length of wheel seats	0	10
Length of journals	0	$7\frac{1}{2}$
Length of end collars	0	1
Diameter of middle	0	$4\frac{1}{2}$
Diameter of wheel seats	0	5
Diameter of journals	0	$3\frac{7}{8}$
Diameter of end collars	0	$4\frac{3}{4}$

FIG. 6.

FORGED SKETCH OF AXLE AS UNDER.



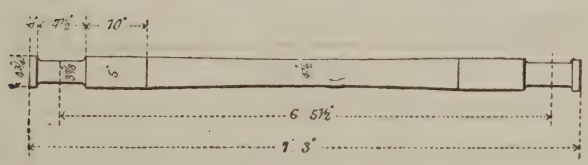
TEST No. 2, OF A BEST BEST FAGOTTED SCRAP CARRIAGE AXLE (MARK, "WORTLEY BEST BEST"). MAY 1ST, 1876.

Distance between bearings.	Height from which weight of 2369 lbs. falls (21 cwt. 0 qr. 17 lbs.).	Number of blows.	Deflection from end to end.	Deflection between bearings.
ft. in.	ft. in.			
3 6	21 9	1	12½ in.	5½ in.
			Turned over.	
3 6	21 9	2	Straight	Straight
"	"	3	12½ in.	5½ in.
			Turned over.	
3 6	21 9	4	1½ in. from being straight	½ in. from being straight
"	"	5	13¾ in.	6 in.
			Turned over.	
3 6	21 9	6	3¼ in. from being straight	1¼ in. from being straight
"	"	7	Broken	

	ft.	in.
Total length of axle	7	3
Length from centre to centre of journals	6	5½
Length of wheel seats	0	10
Length of journals	0	7½
Length of end collars	0	1
Diameter of middle	0	4½
Diameter of wheel seats	0	5
Diameter of journals	0	3⅞
Diameter of end collars	0	4¾

FIG. 7.

FORGED SKETCH OF AXLE AS UNDER.



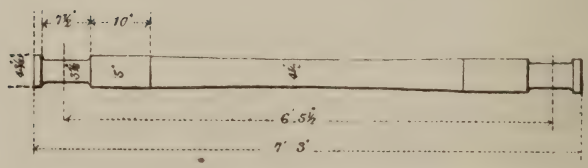
TEST NO. 3, OF A BEST BEST FAGOTTED SCRAP CARRIAGE AXLE (MARK, "WORTLEY BEST BEST"). MAY 10TH, 1876.

Distance between bearings.	Height from which weight of 2369 lbs. falls (21 cwt. 0 qr. 17 lbs.).	Number of blows.	Deflection from end to end.	Deflection between bearings.
ft. in.	ft. in.			
3 6	17 0	1	9 in.	5 in.
			Turned	*over.*
3 6	17 0	2	$2\frac{3}{4}$ in. from being straight	$1\frac{1}{2}$ in. from being straight
,,	,,	3	$5\frac{3}{4}$ in.	3 in.
			Turned	*over.*
3 6	17 0	4	3 in. past straight	$1\frac{5}{8}$ in. past straight
,,	,,	5	Broken	

	ft.	in.
Total length of axle	7	3
Length from centre to centre of journals	6	$5\frac{1}{2}$
Length of wheel seats	0	10
Length of journals	0	$7\frac{1}{2}$
Length of end collars	0	1
Diameter of middle	0	$4\frac{1}{2}$
Diameter of wheel seats	0	5
Diameter of journals	0	$3\frac{7}{8}$
Diameter of end collars	0	$4\frac{3}{4}$

FIG. 8.

FORGED SKETCH OF AXLE AS UNDER.



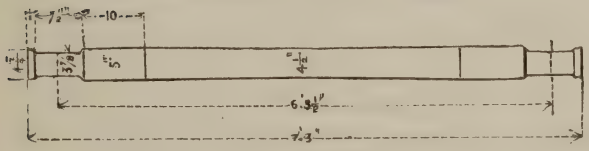
TEST NO. 4, OF A BEST BEST FAGOTTED SCRAP CARRIAGE AXLE (MARK, "WORTLEY BEST BEST"). SEPTEMBER 1ST, 1876.

Distance between bearings.	Height from which weight of 2369 lbs. falls (21 cwt. 0 qr. 17 lbs.).	Number of blows.	Deflection from end to end.	Deflection between bearings.
ft. in.	ft. in.			
3 6	15 0	1	8 in.	3½ in.
			Turned	*over.*
3 6	15 0	2	1½ in. past straight	½ in. past straight
"	"	3	8½ in.	3½ in.
			Turned	*over.*
3 6	15 0	4	1¾ in. past straight	¾ in. past straight
"	"	5	8½ in.	3½ in.
			Turned	*over.*
3 6	15 0	6	1¾ in. past straight	¾ in. past straight
"	"	7	8½ in.	3½ in.
			Turned	*over.*
3 6	15 0	8	Broken	

	ft.	in.
Total length of axle	7	3
Length from centre to centre of journals	6	5½
Length of wheel seats	0	10
Length of journals	0	7½
Length of end collars	0	1
Diameter of middle	0	4½
Diameter of wheel seats	0	5
Diameter of journals	0	3⅞
Diameter of end collars	0	4¾

FIG. 9.

FORGED SKETCH OF AXLE AS UNDER.



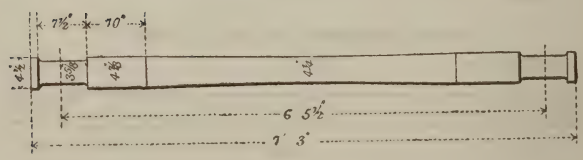
TEST NO. 5, OF A BEST BEST FAGOTTED SCRAP CARRIAGE AXLE (MARK, "WORTLEY BEST BEST"). AUGUST 23RD, 1876.

Distance between bearings.		Height from which weight of 2369 lbs. falls (21 cwt. 0 qr. 17 lbs.).		Number of blows.	Deflection from end to end.	Deflection between bearings.
ft.	in.	ft.	in.			
3	6	17	0	1	$11\frac{1}{2}$ in.	$5\frac{1}{4}$ in.
					Turned	*over.*
3	6	17	0	2	Straight	Straight
"		"		3	10 in.	$4\frac{1}{2}$ in.
					Turned	*over.*
3	6	17	0	4	Broken	

	ft.	in.
Total length of axle	7	3
Length from centre to centre of journals	6	$5\frac{1}{2}$
Length of wheel seats	0	10
Length of journals	0	$7\frac{1}{2}$
Length of end collars	0	1
Diameter of middle	0	$4\frac{1}{4}$
Diameter of wheel seats	0	$4\frac{7}{8}$
Diameter of journals	0	$3\frac{5}{8}$
Diameter of end collars	0	$4\frac{1}{2}$

FIG. 10.

FORGED SKETCH OF AXLE AS UNDER.



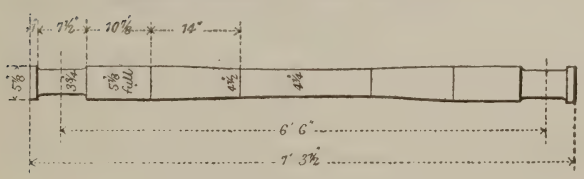
TEST NO. 6, OF A BEST BEST FAGOTTED SCRAP CARRIAGE AXLE (MARK, "WORTLEY BEST BEST"). DECEMBER 15TH, 1874.

Distance between bearings.		Height from which weight of 2369 lbs. falls (21 cwt. 0 qr. 17 lbs.).		Number of blows.	Deflection between bearings.
ft.	in.	ft.	in.		
3	6	17	3	1	$4\frac{3}{4}$ in.
					Turned over.
3	6	16	6	2	Straight
,,		17	3	3	$4\frac{1}{2}$ in.
					Turned over.
3	6	16	6	4	Re-deflected $\frac{3}{16}$ in.
,,		17	3	5	$4\frac{1}{8}$ in.
					Turned over.
3	6	16	6	6	Re-deflected $\frac{1}{2}$ in.
,,		17	3	7	4 in.
					Turned over.
3	6	16	6	8	Re-deflected $\frac{5}{8}$ in.
,,		17	3	9	4 in.
					Turned over.
3	6	16	6	10	Broken.

	ft.	in.
Total length of axle	7	$3\frac{1}{2}$
Length from centre to centre of journals	6	6
Length of wheel seats	0	$10\frac{7}{8}$
Length of journals	0	$7\frac{1}{2}$
Length of end collars	0	1
Diameter of middle	0	$4\frac{1}{4}$
Diameter of wheel seats	full	$5\frac{1}{8}$
Diameter of journals	0	$3\frac{3}{4}$
Diameter of end collars	0	$5\frac{1}{8}$

FIG. 11.

FORGED SKETCH FO AXLE AS UNDER.



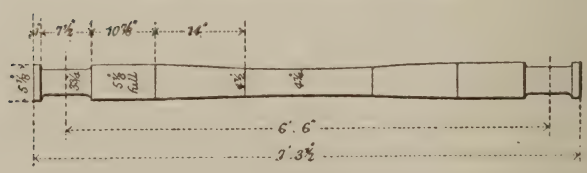
TEST NO. 7, OF A BEST BEST FAGOTTED SCRAP CARRIAGE AXLE (MARK, "WORTLEY BEST BEST"). DECEMBER 15TH, 1874.

Distance between bearings.	Height from which weight of 2369 lbs. falls (21 cwt. 0 qr. 17 lbs.).	Number of blows.	Deflection from end to end.
ft. in.	ft. in.		
3 6	17 6	1	$12\frac{5}{8}$ in.
			Turned over.
3 6	17 6	2	Straight
"	"	3	$11\frac{3}{4}$ in.
			Turned over.
3 6	17 6	4	Straight
"	"	5	Broken

	ft.	in.
Total length of axle	7	$3\frac{1}{2}$
Length from centre to centre of journals	6	6
Length of wheel seats	0	$10\frac{7}{8}$
Length of journals	0	$7\frac{1}{2}$
Length of end collars	0	1
Diameter of middle	0	$4\frac{1}{4}$
Diameter of wheel seats	full	$5\frac{1}{8}$
Diameter of journals	0	$3\frac{3}{4}$
Diameter of end collars	0	$5\frac{1}{8}$

FIG. 12.

FORGED SKETCH OF AXLE AS UNDER.



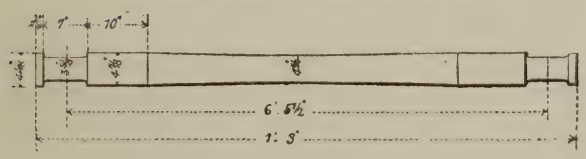
TEST NO. 8, OF A BEST BEST FAGOTTED SCRAP CARRIAGE AXLE (MARK, "WORTLEY BEST BEST"). APRIL 23RD, 1874.

Distance between bearings.	Height from which weight of 1800 lbs. falls (16 cwt. 0 qr. 8 lbs.).	Number of blows.	Deflection from end to end.
ft. in.	ft. in.		
3 6	19 0	1	8½ in.
			Turned over.
3 6	19 0	2	½ in. past straight
"	"	3	9 in.
			Turned over.
3 6	19 0	4	Straight
"	"	5	Broken

	ft.	in.
Total length of axle	7	3
Length from centre to centre of journals	6	5½
Length of wheel seats	0	10
Length of journals	0	7
Length of end collars	0	1¼
Diameter of middle	0	4¼
Diameter of wheel seats	0	4⅞
Diameter of journals	0	3⅝
Diameter of end collars	0	4⅝

FIG. 13.

FORGED SKETCH OF AXLE AS UNDER.



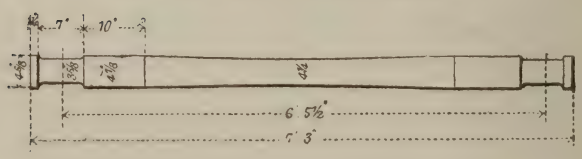
TEST NO. 9, OF A BEST BEST FAGOTTED SCRAP CARRIAGE AXLE (MARK, "WORTLEY BEST BEST"). APRIL 23RD, 1874.

Distance between bearings.		Height from which weight of 1800 lbs. falls (16 cwt. 0 qr. 8 lbs.).		Number of blows.	Deflection from end to end.
ft.	in.	ft.	in.		
3	6	19	0	1	$8\frac{1}{8}$ in.
					Turned over.
3	6	19	0	2	Straight
"		"		3	$6\frac{1}{4}$ in.
					Turned over.
3	6	19	0	4	Broken

	ft.	in.
Total length of axle	7	3
Length from centre to centre of journals	6	$5\frac{1}{2}$
Length of wheel seats	0	10
Length of journals	0	7
Length of end collars	0	1
Diameter of middle	0	$4\frac{1}{4}$
Diameter of wheel seats	0	$4\frac{7}{8}$
Diameter of journals	0	$3\frac{5}{8}$
Diameter of end collars	0	$4\frac{5}{8}$

FIG. 14.

FORGED SKETCH OF AXLE AS UNDER.



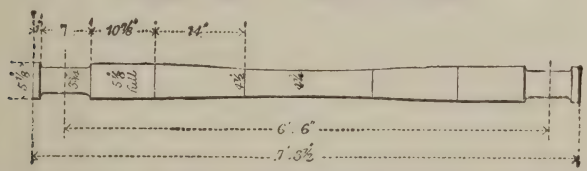
TEST NO. 10, OF A BEST BEST FAGOTTED SCRAP CARRIAGE AXLE (MARK, "WORTLEY BEST BEST"). SEPTEMBER, 1874.

Distance between bearings.		Height from which weight of 2369 lbs. falls (21 cwt. 0 qr. 17 lbs.).		Number of blows.	Deflection between bearings.
ft.	in.	ft.	in.		
3	6	17	6	1	$5\frac{1}{2}$ in.
					Turned over.
3	6	17	6	2	Straight
"		"		3	5 in.
					Turned over.
3	6	17	6	4	Straight
"		"		5	Broken

	ft.	in.		ft.	in.
Total length of axle ..	7	$3\frac{1}{2}$	Length of end collars ..	0	1
Length from centre to centre of journals	6	6	Diameter of middle	0	$4\frac{1}{4}$
Length of wheel seats ..	0	$10\frac{7}{8}$	Diameter of wheel seats ..	full	$5\frac{1}{8}$
Length of journals	0	7	Diameter of journals ..	0	$3\frac{3}{4}$
			Diameter of end collars ..	0	$5\frac{1}{8}$

FIG. 15.

FORGED SKETCH OF AXLE AS UNDER.



On examination of the foregoing experiments, more particularly on reference to Nos. 1, 3, 5, 7, 9, 10, 13, one circumstance is noticeably worthy of remark, and which can scarcely be called a mere coincidence. It will be seen in some of the axles the deflection becomes less as the number of blows increases, this being contrary to one's expectations. May not this in some measure be due to the fact that the repetition of heavy blows has a tendency to alter the molecular structure, making the iron more crystalline and harder, in the same way that repeated hammering of fibrous iron in the cold renders it crystalline in nature, and consequently harder?

It must be generally admitted that a thoroughly trustworthy, satisfactory, and uniform system of testing railway axles, and one capable of being universally adopted, is at present much wanted, as the methods now employed are as various as the diversities of the opinion entertained by engineers on this important question. Many adopt what may be called the gravitation or falling weight test, giving the axle a few extremely

severe, sudden, and destructive blows from a heavy falling weight. Others, again, do not place too much reliance on this process, choosing rather simply to bend the axle to be examined to a given deflection—as an extreme test till both ends meet—by means of great hydraulic or other pressure continuously applied. Such seek to avoid sudden heavy shocks and vibrations, and contend that the nature of the material of which an axle is composed is better determined by this gradual application of strong pressure than by the use of violently applied force.

TEST NO. 11, OF A BEST SCRAP AXLE (MARK, "WORTLEY BEST"). MARCH 3RD, 1871.

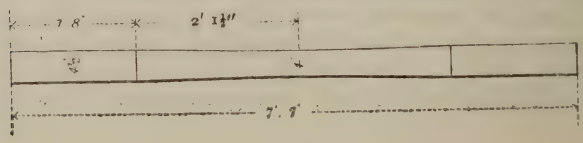
Distance between bearings.	Height from which weight of 2369 lbs. falls (21 cwt. 0 qr. 17 lbs.).	Number of blows.	Deflection between bearings.
ft. in.	ft. in.		in.
4 0	6 0	1	2
"	"	2	1½
"	"	3	1¼
"	"	4	1
"	"	5	1
			Total 6¾
			Turned over.
			in.
4 0	6 0	1	Re-deflected 2
"	"	2	" 1½
"	"	3	" 1½
"	"	4	" 1¼
"	"	5	" 0½
			Total 6¾
			Turned over.
			in.
4 0	8 0	1	2¼
"	"	2	2
			Total 4¼

The axle neither cracked nor broken.

	ft.	in.		ft.	in.
Total length of axle	7	7	Diameter of middle ..	0	4
Length of parallel part at ends	1	8	Diameter of parallel part at each end	0	4½
Length of tapers	2	1½			

FIG. 16.

FORGED SKETCH OF AXLE AS UNDER.



TEST No. 12, OF A BEST SCRAP AXLE (MARK, "WORTLEY BEST"). APRIL 20TH, 1874.

Distance between bearings.	Height from which weight of 2369 lbs. falls (21 cwt. 0 qr. 17 lbs.).	Number of blows.	Deflection between bearings.
ft in.	ft. in.		
5 0	5 0	1	3 in.
,,	,,	2	$5\frac{5}{8}$ in.
,,	,,	3	$7\frac{3}{8}$ in.
			Turned over.
5 0	5 0	4	$4\frac{3}{4}$ in.
,,	,,	5	$3\frac{1}{4}$ in.
,,	,,	6	Re-deflected 1 in.
,,	6 0	7	,, 1 past straight
,,	,,	8	,, $3\frac{7}{8}$
,,	,,	9	,, 6
,,	,,	10	,, 8
			Turned over.
5 0	5 0	11	$6\frac{1}{8}$ in.
,,	5 10	12	$4\frac{1}{8}$ in.
,,	6 0	13	$2\frac{3}{4}$ in.
,,	,,	14	Broken

	ft.	in.
Total length of axle	6	6
Diameter of middle	0	$4\frac{1}{4}$

TEST No. 13, OF A BEST SCRAP AXLE FORGING. OCTOBER 1ST, 1870.

Distance between bearings.	Height from which weight of 2369 lbs. falls (21 cwt. 0 qr. 17 lbs.).	Number of blows.	Deflection from end to end.	Deflection between bearings.
ft. in.	ft. in.		in.	in.
5 0	6 0	1	$2\frac{5}{8}$	$1\frac{1}{2}$
,,	,,	2	$2\frac{1}{8}$	$1\frac{1}{8}$
,,	,,	3	2	$1\frac{1}{8}$
,,	,,	4	$1\frac{1}{2}$	$\frac{3}{4}$
,,	,,	5	$1\frac{1}{4}$	$\frac{3}{4}$
,,			Total $9\frac{1}{2}$	Total $5\frac{1}{4}$
			Turned over.	
			in.	in.
5 0	6 0	1	Re-deflected $1\frac{1}{4}$	Re-deflected $\frac{1}{2}$
,,	,,	2	,, $1\frac{7}{8}$	,, $1\frac{1}{8}$
,,	,,	3	,, $1\frac{3}{8}$	,, $\frac{7}{8}$
,,	,,	4	,, $1\frac{1}{2}$	,, $\frac{3}{4}$
,,	,,	5	,, $1\frac{5}{8}$	,, $\frac{1}{8}$
,,	,,	6	,, $1\frac{5}{8}$	,, $\frac{7}{8}$
			Total $9\frac{1}{4}$	Total 5

Diameter of middle .. .. $5\frac{1}{16}$ in. bare.

Some incline to the opinion that a careful examination of the material composing an axle, showing its tensile strain, elasticity, contraction of area at fracture, &c., ought to suffice for all practical purposes, and with much reason. It cannot be doubted this latter method is decidedly the more correct and purely scientific in principle, and in all respects the most complete and exhaustive; still there are some points that require consideration in the application of even this scientific test.

The falling weight test, with all the modifications of its application, is in itself only at best a rough-and-ready way of examining axles, but at the same time it must be admitted that iron or steel axles which will stand such remarkably severe punishment as the foregoing tests demand are of excellent quality, and well able, in practical working, to cope with any strains they may have to endure. In one sense it may be said to approximate more closely to the extreme shocks ironwork is likely to meet with in actual wear and tear, than the more exact method of steadily increased pressure. It cannot be denied, however, that there is considerable danger of arriving at an unjust conclusion as to the quality of an iron or steel axle when tested by this method alone, the axle having perhaps broken after having received only a limited number of heavy blows, whereas in reality such iron or steel axle may be quite equal in tensile strength, and possibly even superior in quality to another that may have stood a greater number of blows. The only difference being, that one is somewhat more crystalline, and consequently harder and more brittle in nature, than the other which resisted greater destructive force by the falling weight. This apparent irregularity is not unfrequently met with in practice, as the following examples illustrate:—

A is a piece of iron cut from a best best scrap axle after it had been tested to destruction in the following remarkable manner as seen in Test No. 1. It will be admitted this axle gave most extraordinary results.

A.—Best Best Scrap Fagotted Railway Carriage Axle (Mark, "Wortley Best Best).

Distance between bearings.	Height from which weight of 2369 lbs. falls (21 cwt. 0 qr. 17 lbs.).	Number of blows.	Deflection from end to end.	Deflection between bearings.
ft. in.	ft. in.			
3 6	17 0	1	9½ in.	4¼ in.
			Turned	*over.*
3 6	17 0	2	1¼ in. past straight	¾ in. past straight
,,	,,	3	8 in.	3½ in.
			Turned	*over.*
3 6	17 0	4	Re-deflected 1 in.	Re-deflected ¾ in.
,,	,,	5	8 in.	3½ in.
			Turned	*over.*
3 6	17 0	6	Re-deflected 1¼ in.	Re-deflected ¾ in.
,,	,,	7	7¾ in.	3½ in.
			Turned	*over.*
3 6	17 0	8	Re-deflected 1¼ in.	Re-deflected ¾ in.
,,	,,	9	7 in.	3 in.
			Turned	*over.*
3 6	17 0	10	Re-deflected 2 in.	Re-deflected 1¼ in.
,,	21 9	11	6¾ in.	3 in.
			Turned	*over.*
3 6	21 9	12	Re-deflected 3½ in.	Re-deflected 1¾ in.
,,	,,	13	Broken	

	ft.	in.		ft.	in.
Total length of axle	7	3	Length of end collars	0	1
Length from centre to centre of journals	6	5½	Diameter of middle	0	4½
Length of wheel seats	0	10	Diameter of wheel seats ..	0	5
Length of journals	0	7½	Diameter of journals	0	3⅞
			Diameter of end collars ..	0	4¾

B.—Best Best Carriage Axle. Made to the following Forged Sizes and Tested May 10th, 1876 (not of Wortley Manufacture).

Distance between bearings.	Height from which weight of 2369 lbs. falls (21 cwt. 0 qr. 17 lbs.).	Number of blows.	Deflection from end to end.	Deflection between bearings.
ft. in.	ft. in.			
3 6	17 0	1	10½ in.	5⅝ in.
			Turned	*over.*
3 6	17 0	2	Broken	

	ft.	in.		ft.	in.
Total length of axle	7	2½	Diameter of middle ..	0	4
Length of wheel seats ..	0	10	Diameter of wheel seats	0	4⅞ bare
Length of journals	0	7	Diameter of journals ..	0	3½ bare

B is a piece of iron cut from another best best axle (not of Wortley manufacture) that had been tested as shown in the preceding table B, standing well under this severe method; but certainly no way approaching the results obtained from the former axle. Now if this falling weight test is to be taken alone as the standard test to indicate comparatively the quality of the two axles examined, there is unquestionably no other course than to set down axle B at once as vastly inferior to A. As regards both quality of material and workmanship such was not the case, the fracture of the axles being very similar, except that B showed a more fine grained and crystalline structure than A, whose fracture gave about 80 per cent. of clearly defined strong fibre. When examined for tensile strain axle A gave, as might be expected, higher results than axle B. The difference being about 14 per cent. in favour of A, as indicated by the record of experiments given in Tables 3 and 4 on opposite page.

These experimental observations would make the two methods of testing in a manner not very apparently coincide in results, and indicate for purposes of exact comparison the unreliability of the falling weight method when used alone. A further instance of this may be seen on reference to the tests of axles made by the Engineers and Architects' Society of Austria, which appeared in 'The Engineer,' February 2nd, 1877. Mr. Browne, the author of the communication, calling attention to the numerous differences of the results, amongst other remarks, states that, "The behaviour of the iron axles was no less remarkable; one of them completely distanced all competitors, both Bessemer steel, cast steel, and iron, and carried off all the honours as to struggle. Here they took a high rank, the worst of the two being only surpassed by four out of thirteen Bessemer steel axles, which were tested in the same manner." Mr. Walter R. Browne concludes his admirable paper by remarking, "Probably, however, the chief feeling of an English engineer with regard to these experiments is one of satisfaction that he has not in this instance yielded to the fascination of steel like his brethren in Austria, but has been content to rely on the old-fashioned material, wrought iron."

The foregoing experiments, made by the Engineers and Architects' Society of Austria, afford one some idea of the discrepancy of results given by the falling weight test. The falling weight test as now generally applied is certainly open to various objections. By this process the axle is frequently tested and punished most severely in the middle—that part which in practical wear is less liable to injury or fracture from sudden shocks, there being undoubtedly in ordinary work a

TABLE No. 3.

Description.	Original.		Ultimate stress.		Ratio of elastic to ultimate.	Contraction of area at fracture.	Extension.		Appearance of fracture.
	Diameter.	Area.	Elastic per sq. in.	Ultimate per sq. in.			At 40,000 lbs. per sq. in.	Ultimate.	
	turned.	sq. in.	lbs.	lbs.	per cent.	per cent.	per cent.	per cent.	
Piece of axle A turned down to $2\frac{1}{4}$ in.	2·257	4·000	23,800	48,372 **21·59** tons	49·2	25·3	4·79	19·7	80 per cent. *fibrous.* 20 per cent. *crystalline.*
Piece of hammered iron made same way as axle A, $2\frac{11}{16}$ in. diameter ..	1·597	2·000	28,200	48,790 **21·78** tons	57·7	26·3	3·53	17·9	100 per cent. fibrous.

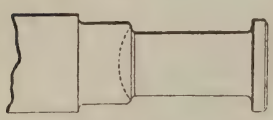
Description.	Original.		Ultimate stress.		Fractured.				Stress per square inch of fractured area.	Extension.		Appearance of fracture.
	Size.	Area.	Total.	Per square inch of original area.	Size.	Area.	Difference.			inch.	per cent.	
							Area.	per cent.				
				lbs. tons.								
$2\frac{1}{2}$ in. diameter, piece of axle B turned to above size	2·52	4·985	211,620	42,451 = **19·00**	2·46	4·750	0·235	4·7	44,551	0·62	6·2	100 per cent. crystalline.

TABLE No. 4, PIECE CUT FROM AXLE A (TEST No. 1) ADJACENT TO THE FRACTURE.

Description.	Original.		Ultimate stress.		Fractured.				Stress per square inch of fractured area.	Extension.		Appearance of fracture.
	Size.	Area.	Total.	Per square inch of original area.	Size.	Area.	Difference.			inch.	per cent.	
							Area.	per cent.				
			lbs.	lbs. tons.								
Piece of axle A, adjacent to the fracture	2·52	4·985	170,540	34,210 = **15·2**	2·23	3·904	1·081	21·7	43,683	0·67	6·7	Fibrous, but the welds loose.

certain amount of elastic spring in the length of the axle between the two wheel bosses. When therefore the test of impact is thus applied only to the middle of an axle, that small part doing the chief work, and far more liable to injury or fracture, viz. the journal — back of wheel seat in juncture between the journals and boss—thus really undergoes no severe test at all. As an actual fact, the journals of axles have been known to break and fly off as a result of the sudden concussion of the falling weight on the middle, even where the axle has not fractured in the middle, though one would not be inclined to place much reliance on the quality of such brittle material.

Fig. 17.



Another modification of the impact test is used by some engineers, with a view to ascertaining the uniform toughness and tenacity of an axle throughout from end to end—a not unnecessary precaution, as will be seen from the variable nature of even two best steel axles when made from the same ingot. This consists simply in applying proportionately the falling weight test to both the ends, as well as to the middle, the axle being moved to permit the weight to fall so as to test the journals at each end.

So far as the test by impact goes, the author inclines to the opinion that the best and most satisfactory way of applying it is to allow a greater number of lighter blows to descend on an axle until it reaches a certain given deflection. As a scientific process, however, the application of a steady measurable pressure, hydraulic or otherwise, would be incomparably better, and more rational than the elephantine crashes and other *outré* tests recently required by some railway companies.

An axle submitted to such enormous blows cannot be said to have been scientifically and accurately tested in the proper sense of the term. The fibre and grain of the iron is simply distorted or destroyed, and the molecular arrangements of its component parts, after even the first heavy blow, cannot but be partially or altogether displaced. It certainly may be said that the axle has been tested to destruction. Destruction is all that appears to be aimed at in these extraordinarily severe tests, as almost every fibre of which an axle is composed must be completely contorted. The following observation goes far to prove this, the sample experimented on being cut from near the middle of axle A, adjacent to the fracture. This severe gravitation test so far shook and loosened the fibres and welds as to show a great reduction in tensile resistance, as results indicate in Table 4.

Moreover, it is somewhat difficult to see any proportionate relationship that can exist between these severe tests and the real capacity for actual work possessed by an axle in practical wear and tear—which, after all, is the proper measure of its value. Previous experiments have shown that the actual resisting quality and real tensile endurance of an axle may be misjudged, and an unjust and arbitrary conclusion as to its quality be arrived at, by solely relying on the gravitation test. Of course, on the one hand, it is to be admitted that a material which will endure such severe handling must, of necessity, be of super-excellent quality; yet, on the other hand, it by no means follows that another axle which will not withstand such enormous blows must be set down as of such inferior quality as the comparative results of this testing might seem to indicate. Although the test by impact may be said to represent most nearly the real shocks an axle may have to endure in its work, yet in carefully examining and comparing the quality of axles, a sole and absolute dependence on the results of the falling weight test only would tend to mislead. There have been suggestions as to the desirability of having each individual axle tested; but the great difficulty in arranging such a test is to draw the line, so that in the examination the axle shall not be so far injured, or its fibres so damaged, that there would be any risk in its being used. The appearance of the fracture of an axle, whether fibrous, close fine grain crystal, or coarsely crystalline, gives a very good indication to the experienced eye as to the quality of the material.

In a really correct process of axle testing, the amount of testing force actually applied should be measurable and easily indicated, and the force thus applied should be greater than, and also bear some relative proportion to, the greatest amount of shock an axle is likely to meet with in its real working. To ascertain this is a matter of no small difficulty, as the shocks, blows, and concussions of various kinds occurring in railway work are legion. For present practical purposes, however, we may roughly regard them as coming under one head, though the sources from whence they are derived are innumerable. Thus we have:—

(1) Vertical concussions, viz. all blows of whatever kind, arising from whatever cause, that an axle may have to endure, the destructive force being in the perpendicular to the rail. As for example, the sudden shock which would be conveyed to an axle in an upward direction, if the wheel should in travelling suddenly run over any hard unyielding obstacle it may encounter. In this case there would be both the estimated force of the shock itself to be arrived at, and the inertia to be over-

come of actual dead weight on the axle. On the smaller scale this is constantly occurring, owing to slight irregularities of the permanent road, and although injury to the axle, &c., is obviated by the springs, yet in occasional accidental cases the shock is not small.

(2) Then there are what may be called horizontal concussions —such as are continually being imparted to axles at the journals, during the starting and shunting of trains. These lateral shocks from innumerable causes are not only frequent but often heavy, the force of the blows impinging at right angles with the dead weight or inertia of the load. It is true the draw-hook springs and buffer springs very greatly mitigate this class of concussions, but the destructive force at work in shunting is great, more especially to waggons unprovided with buffer springs. In either of the foregoing classes the chief risk is in the snapping off of the journal.

(3) In addition may be placed collisional concussions, made up of altogether unexpected, crashing, destructive forces, the direction and power of which cannot well be defined, as in the event of some terrible collision, in which the destructive force may strike the axle, not at right angles with the line of its centre, but at any conceivable tangent, the force of the impact being received at any angle, with the ends, the middle, or other part of the axle, and during which any other portion of the axle may be severely punished at the same moment and along with the journal. As a preliminary inquiry, it would be desirable to obtain a rough approximate measurement of the force of blows an axle undergoes in real wear and tear. This could in some measure be attained by having a well-loaded truck fitted with special axle-guard irons, and by having springs of known elasticity so arranged, with an indicator in the form of a self-fastening clip, which would show the greatest elastic stress brought into play during a given time of running. Experiments might also be tried by letting the loaded waggon run at known speeds over certain small solid obstructions placed on each rail. The limit of the depression of the springs—presuming they were not broken—as shown by the self-fastening clip, ought thus to afford some data as to the force of the shock. An attempt might be made on similar principles to ascertain the extent of some of the ordinary longitudinal shocks of shunting, &c. Whatever the amount of the shock was thus found to be in ordinary eventualities, the test to be applied to axles should bear some relative greater proportion thereto. Whatever may be thought of these crude suggestions, most engineers, it may be presumed, feel the need of some uniform normal test of a

reasonable kind for railway axles, and, acting on scientific principles, such test undoubtedly ought to bear distinct proportion to the actual work an axle will be called upon to perform.

DISCUSSION.

Mr. PENDRED said that there was scarcely a word which Mr. Andrews had written with which he (Mr. Pendred) did not agree; but the paper was incomplete, inasmuch as, although it described the axles and the tests to which they were submitted, it did not give any information concerning the process by which the axles were made, or as to whether they were made from piles or scrap. He believed that most engineers who had had any experience in ironworks would agree with him in the opinion that the tests, no matter how well they might be carried out, were comparatively insignificant and unsatisfactory as compared with having a thoroughly good specification, and having the work done honestly and properly, and at a proper price, by a thoroughly good firm. The axle which had been shaken to pieces, and which was now exhibited, had divided in a very singular way. It had gone, practically, into three pieces, and apparently, if the test had been carried a little farther, it would have gone into four pieces. He should like to know whether that axle had been made of four bars rolled together in the first instance. If it had been, there was a very singular fact connected with it, because in the specimen it was utterly impossible to detect any semblance of a weld; and if the axle had been rolled from four bars, the welding must have been wonderfully perfect. If it was admitted that it had been made from four bars and welded in a wonderfully perfect manner, they would be next met with the extraordinary fact that the bar had separated into four parts. Another point upon which information ought to be given was the temperature at which the axles were tested. The effect of temperature in all kinds of tests of ironwork was exceedingly important. The subject of temperature, its influence on the strength of iron, had been very keenly discussed, both in this country and on the Continent. He did not agree with the view that temperature had no effect whatever on the strength of iron. Perhaps the extent to which frost and heat operated was not generally known. Last winter some rivets which had been supplied for use in the construction of a bridge in one of the midland counties had to be tested. They were ten or twelve inches long, and varied in diameter from about three-quarters to one inch. They were to stand the test of being doubled over on themselves, cold. During a sharp

frost some 1-inch rivets were taken haphazard from a bag in the yard where they had lain all night. They were taken into the forge and put on the anvil, and at the first blow they each broke off under the head. Other rivets were taken from various bags and tested, and the whole was condemned. For some reason with which he (Mr. Pendred) was unacquainted, the foreman of the works took a handful of the rivets and put them inside the fender in the gate-keeper's office. These rivets were then brought back and submitted to the required test, and they bent over just as they were intended to do. They were then put into the testing machine, and they stood a tensile strain of 22 or 23 tons, the strength required being 22 tons. Some rivets which had been taken direct from the bags and tested in the machine without having been warmed by the office fire were unable to stand a greater tensile strain than about 15 tons. Some more rivets were brought in and heated to about 80°, and they all stood the test perfectly, and the result was that the whole of the rivets were accepted as being perfectly good. In precisely the same way, different results might be obtained in testing axles, according to the temperature of the axles when submitted to the test. He had known cases in which railway axles had been condemned by one railway company as being bad, and afterwards sold to another railway company and tested in the summer time and pronounced to be as good axles as were ever used. Another point in connection with the subject of testing was, that as a rule axles seldom broke in the centre, which was the place where they were tested. He had known several cases of broken axles, but he could not call to mind one in which the fracture was in the middle. The axles almost invariably broke at the collars, just inside the wheels, or just outside the wheels. They broke wherever there was a shoulder. The Board of Trade had now made a standing rule that axles should not be passed when the wheel had been forced home against a square collar. They preferred that the wheel should be simply forced upon the axle without being put against a collar at all, and they did not allow sharp angles in any corners connected with the journals. The influence which was exerted by the form of an angle or collar, or by any enlargement on a shaft, could not be over-estimated. That influence operated in the making of a crank shaft, and in every case in which a collar was placed on a bar of iron. The best way to get a good axle was to be very careful about its shape, and the firm to which the order was given, to have a good specification for it, and to put as little reliance as possible upon the falling weight test.

Mr. Horsley said that he should have wished to have heard from the author what was the real cause of the breaking of the axles, and he (Mr. Horsley) believed that a great many axles were damaged by getting hot through running, and then cooling again, and so on alternately. When a pupil in an ironworks in Yorkshire, which were not very far from the Wortley Ironworks spoken of in the paper, the firm had a very good price and made very good axles. In those days the fagot, instead of being in four pieces, would be in about twelve, and the bars would be rolled out and then cut off into short lengths and fagotted together again; then the axle would be rolled and hammered. It would be almost like a bundle of wires hammered together, and strength was obtained in that way. He should think that the tensile strength would be a great deal more than that of an axle in which the fagot was made of only four pieces. The axle which had been exhibited appeared to him to have been damaged in the testing. The tensile strength appeared to be almost gone, and the sample looked like No. 1 cast iron. He should like to ask the author why the structure looked so crystalline, and further, whether the iron was made of native or foreign ore. It was a fact that good argillaceous ore yielded the iron of which axles ought to be made. He believed that most of the failures in axles were due to the axles having been alternately hot and cold, and by that means the iron perished. An axle had been shown which had one end cut off close to where it had been turned, and the two ends showed a difference of seven tons between their tensile strengths. He believed that iron should always be made warm before being bent, and that when bent cold the strength was reduced by one-third.

Mr. Beaumont said that the author objected very much to the blow test, though it would seem that the blow test must be really necessary, inasmuch as the heavier strains visited upon an axle in actual work had very much the character of a blow, the difference being, that while in the tests the blow was that of a heavy weight falling at the comparatively small velocity due to gravity, in practice it was a series of very sharp rapid blows quickly repeated. When a train was running, the wheels were lifted up and dropped down again on the very many irregularities of the line at a velocity which induced severe shocks. The velocity at which impact shocks were transmitted through the wheels to the axle was not simply that of gravity or that of the velocity of the train, but very many of the shocks were thus transmitted at the velocity of recoil of a loaded spring, which was probably as much as 1300 feet per second.

Thus it would seem that a blow test was necessary to prove whether an axle would withstand the strains involved in actual work; but to approach more nearly to an imitation of the latter, the blows should be less heavy but delivered at much greater velocity. On some of the railways on the Continent, the engineers had made it a rule to take out the axles after they had run a certain number of miles and anneal them, whether they indicated the necessity for such treatment or not. The object of this practice was that in cases in which a crystalline structure had been induced by the continued hammering of the wheels along the lines under high velocities, the fibrous character of the iron might be restored. The author had mentioned the case of the end of an axle dropping off under the slow gravity test. If that axle had been tried by means of the simple tensile tests which the author proposed, its head would not have dropped off, and yet any breaking strains which an axle had to withstand were just those that would break off its end. Hence it seemed to him that some such test as the blow test was as really necessary in the case of axles as any test which could be suggested.

The author having made a sketch on the black-board showing a cross-section on the pile from which the axles under discussion were made, this pile consisting of sixteen bars one inch square fagotted together,

Mr. Halpin said that the question of axles was discussed some time ago before a kindred society, and an axle of a very similar kind, as far as the mode of manufacture went, was very severely criticised. It was the well-known axle made by the Patent Shaft Company, and the fault that was found with it was that there was less provision in it than even in ordinary axles for the cinder to get away, so that in the Patent Shaft Company's axle there was more cinder and less iron than in axles of the ordinary kind. During the discussion to which he referred a great deal of attention was directed to the way in which the old axles were made; and the conclusion arrived at was, that in the old form of axle, which was composed of a number of flat, or sometimes even convex bars, there was a better result after hammering. The author objected to the method of testing with falling weights as followed by railway companies; and the manner of obtaining results which was described in the paper would naturally be a very rude one. It was very much like hiring a man by time and saying that they would give him 100*l.* or 1000*l.*, without saying whether the sum which was mentioned was to be in payment for a year's or for a day's work. Two quantities were requisite in

order to make the statement definite. To say that an axle must stand 25 tons or 21 tons tensile stress per square inch was perfect nonsense, because some iron would stand any amount of tensile stress and be the greatest possible rubbish. The proposal first made many years ago, as he thought by Mr. Mallett, was, that iron should be tested by the amount of work done in rupturing it, or by a certain weight into a certain elongation, or what might be called under some circumstances of elongation, the reduction of cross-sectioned area. If as a standard test a certain cross-section of iron, and a certain amount of elongation produced by a certain load were taken, a certain amount of work done would result; or, if a certain amount of weight into a certain reduction of cross-sectional area were taken, a certain amount of work done would also result. But if a test were merely made without any reduction of sectional area, or without any elongation, no result would be arrived at at all, as cast iron, or in other words a very untrustworthy material, might conform to such a test. Mr. Pendred had said that he had never known a case in which an axle broke in the centre, and that axles usually broke close to the boss or beside the journal. He (Mr. Halpin) quite agreed that this was a very usual place for breakage, but it was not an unknown thing for axles to break in the centre. He had known axles to break in the centre and very serious consequences result. Even in an empty goods truck body, weighing from 5 tons to 5½ tons, there would be a widening of the distance between the tops and bottoms of the tyres in opposite wheels varying from one-quarter downwards. As the weight was increased, of course the deflection would be much greater; naturally the deflection would extend more or less all over the axle, but it would be chiefly localized in the centre. It was true that axles broke near the wheels, either inside or outside, in consequence of the solid resistance which they had from the wheels, and also in consequence, as Mr. Pendred had said, of putting on square shoulder collars and things of that kind, and also from another mechanical abortion which was dying out in other countries, namely, the cutting of key-ways in axles. This had been disused for many years on the Continent even with engine axles. If the elongation test was adopted it was of great importance to know upon what lengths the test was made, as the percentages of elongation were most materially affected by this factor.

Mr. Graham Smith said that he quite agreed with all that the last speaker had said in regard to elongation and tensile strength. He had had some experience in iron testing, and he

had found that it was absolutely necessary to take either the elongation or contraction. He fancied that the elongation was of very much more use in actual work than the contraction of area, because it was much more easily ascertained. If two centre punch marks were put on the iron to be tested $6\frac{1}{4}$ inches apart, then every $\frac{1}{16}$-inch that the iron stretched would represent 1 per cent., as there were $\frac{100}{16}$-inch in the length of $6\frac{1}{4}$ inches. This method of ascertaining the elongation was more simple than that of ascertaining the contraction of area, which could not be done properly without much care and accurate instruments. Mr. Pendred in his remarks had referred to long rivets bending double while cold. That was a very ordinary test for all rivets, or at least he (Mr. Smith) had made it an ordinary test, and had used it for short rivets. He might say that from his experience with iron he did not believe that the temperature at which it was tested had much to do with the result. He was quite prepared to guarantee that Lord Ward rivets would as a rule bend double equally as well in the depth of winter as in the middle of summer. Even if iron were at a low temperature at the commencement of a test, its temperature was soon raised by the mechanical work done by the tensile strain or concussive blows to which it was subjected. He believed that the reason why fractures occurred more frequently in railway wheels during the winter was, that the ballast bed being frozen hard it was not able to yield to the train, and consequently a series of small concussions took place, which found out the weak places in the tyres, axles, or rails. He thought that the effect of cold on iron would never be ascertained by the ordinary means of testing, simply because the temperature was at once raised by the application of a load or by blows from a hammer.

Mr. Thomas Andrews, in reply, said, in allusion to Mr. Pendred's remarks as to the number of fagots in the axles, and the material composing them, that they were all made from one uniform material—the best selected and scoured scrap, worked into fagots, $1\frac{5}{8}$ inches square, there being sixteen fagots to a pile. The splitting of a portion of one of the axles under the tensile strain test, the same axle having been previously tested to destruction by the gravitation test, involved some rather interesting facts, and that was why he had brought it up. The fracture was that of an axle which, as he thought they must all admit, had stood very extraordinary tests by the falling weight. This axle had stood thirteen blows from a tup of 21 cwt. falling from heights gradually increasing from 17 feet to 21 feet 9 inches, the axle being turned over after each blow. It would be seen

that after the experiments the fracture presented a crystalline appearance. It also showed fibres opening out in one direction. The other end of the axle farthest removed from the fracture presented no such indications, but was sound in every way. In the above case it seemed certain to him that the heavy blows had, previous to the application of the tensile strain test, really disturbed the fibre of the iron. This view was supported by another comparison. A portion of an axle adjacent to the fracture, and which had previously been tested to destruction by the falling weight test, showed no appearance of internal unsoundness; but on being pulled asunder by tensile strain it split longitudinally as soon as it fractured. As to the temperature, the tests were made at the ordinary atmospheric temperature, whatever it was, whether in winter or in summer. Some of the tests (numbers 6 and 7) were made by the Midland Railway Company's inspector during a severe frost in December, 1874. The axle which stood the thirteen blows was tested in the month of May. He was not prepared to say whether axles broke more readily in frosty than in warm weather, but from his experience of ironwork generally, he should incline to the opinion that they did. As to the crystalline appearance of the iron, it was his opinion that the severe and continued blows that the axles passed through in the tests had tended to crystallize the iron at the fractures. As to Mr. Beaumont's remarks on the method of testing, he quite agreed with that gentleman that the best way of testing axles would be to give them a great number of lighter blows, and he believed that he had mentioned that view in the paper. He had no further remarks to make except to quote the old proverb, "The proof of the pudding is in the eating." The works of which he was the proprietor had, he believed, some three hundred thousand of these axles running on different railways. Many of these had been made before he was born, and he believed that some of these old axles were still running. His firm had never had one of them returned broken. That he regarded as the best proof of quality and the most satisfactory practical test. He begged to thank the Society for the kindness with which they had received his paper, and he should feel it an honour if they would accept a photograph of the old carving showing an old hammer erected in 1713.

The President, on behalf of the Society, said that they were very pleased to receive the photograph as a present from Mr. Andrews. In summing up the discussion, he might say that he had heard nothing to remove the impression which most of them entertained, that a number of blows on a heavy or light object, whether it was a great number of small or a small

number of heavy blows on wrought iron, must tend in the nature of things to convert the fibrous into the crystalline; and, so far as he understood the subject, he should prefer not to take an axle into work which had been tested at all. If he were buying axles for a railway company, his great care would be to satisfy himself, by constant inspection by means of a reliable agent, that all the axles were made from the same fibrous iron and in the same way; and when the axles had been made of the best material, in the best possible manner, with the best possible guarantee that the work had been properly carried out, he would select one axle here and there promiscuously, and test them up to the hilt as samples of the bulk. He did not think that the "falling weight" test was a natural or satisfactory one. He believed that that test tended, more than any other with which he was acquainted, to convert the fibrous into the crystalline, and so to injure the axle, and turn a good thing into a bad thing.

November 3rd, 1879.

ROBERT PAULSON SPICE, President, in the Chair.

MODERN TRAMWAY CONSTRUCTION.

By Alfred Wilkinson Jones.

At a recent meeting it was suggested that a review of the principal systems of Modern Tramway, or Street Railway for the conveyance of passengers, now in use in this country, would be welcomed by the Members of the Society, and the object of the present paper is rather to describe the more generally adopted methods of construction, than to suggest any new improvements or modifications.

The first modern tramway of which we have record was laid in New York, as far back as 1832. The rail (Fig. 1) adopted was of somewhat similar section to the one still used, but was much heavier, and weighed as much as 98 lbs. per yard. The fact of the groove being so wide, and the guard standing fully $\frac{1}{2}$ inch lower than the tread, must have rendered the road both inconvenient and dangerous to ordinary traffic. This line proved anything but a success, and in a short time was taken up. In 1852, however, a second tramway was laid in New York by Mr. Loubat, and the tramway movement speedily became very popular in the United States.

Mr. George Francis Train was the first to introduce the modern tramway into England, a short line in Birkenhead having been laid by him in 1860. This was followed by three short lines in London, and one from Hanley to Burslem, in Staffordshire. In all these lines a step rail was used (Fig. 2), the width of which was 6 inches. This rail proved a failure, probably owing to the fact that the step was $\frac{3}{4}$ inch higher than the level of the roadway, and it was shortly replaced in Birkenhead and the Potteries by a groove-rail, while in London it was simply removed.

The failure of Train's system gave a check to the progress of the tramway movement in this country, and, with the exception of a line laid in Salford, with a central rail (into the groove of which a guide wheel could be lowered) and flat bars forming the rolling surface for ordinary wheels, and a short piece of tramway laid in Liverpool as an experiment, on which Noble's

crescent rail (Fig. 4.) was used, nothing was done until 1868, when the Liverpool Tramways Act was passed. Since that time each year has seen some additions to our lines, and at the present time very few towns of any importance are unprovided with tramways, which, when well constructed, have proved themselves to be, not only a great convenience to the general public, but in most cases a very profitable investment.

Modern tramways may be roughly divided into two classes; firstly, those with wooden, and, secondly, those with metal bearings. Except as regards details of fastenings, there exists but little difference between the various systems of tramways laid with wooden sleepers. The rail usually adopted has in its upper surface a groove to receive the wheel flanges of the cars. It has been rolled in various sections; with a perfectly flat under surface, with one shallow fillet (Fig. 3—early Liverpool rail), with two fillets (Fig. 5—section of rail as first laid by London Tramways Company), or with a broad central fillet (Fig. 6—Glasgow Corporation Tramways first section), but the type almost universally adopted has two slightly tapering fangs of about $1\frac{1}{2}$ inch in depth (Fig. 7). The weight of this double-fanged or box rail varies from 50 to 60 lbs. per yard. The ordinary form of groove is about $1\frac{1}{4}$ inch wide at the top and $\frac{3}{4}$ inch deep, with tapering sides and flat bottom, although in some cases the bottom of the grove is semicircular. The guard is generally corrugated.

The rail is bedded on a longitudinal timber sleeper shaped to fit its under surface, and in most lines this longitudinal rests upon, and is bracketed to, transverse sleepers, placed at regular intervals, and intended to preserve both the gauge and level of the rails. The longitudinal sleeper is occasionally protected at the rail joints by an iron sole-plate (Fig. 8). An improved form of sole-plate has lately been laid by Mr. Kincaid on the Gothenburg tramways. This plate has the section of an inverted channel, and, being punched, serves to fish the rails as well as to protect the sleeper.

The earlier method of securing the rail to its sleeper was by means of a vertical countersunk spike (Fig. 2) or wood screw driven through a hole in the groove. The disadvantages of this form of fastening will at once be evident to the eye of a practical observer, and that its use continued so long a time is to be wondered at. It has now been superseded by the side-dog or staple (Fig. 7) originally designed by Mr. Larsen in 1871, the one end of which is driven through a hole in the fang of the rail, and the other, being jagged, into the timber alone.

For the preservation of the gauge in those lines where no lateral sleepers are used, tie-bars are generally adopted, consisting usually of flat bars swaged and screwed at the ends, which pass through the sleepers and are secured by nuts. On the North Metropolitan lines (Fig. 7) these nuts are only $\frac{1}{4}$ inch thick, so as not to interfere with the setts.

The joints of the longitudinal sleepers sometimes rest in cast-iron chairs (Fig. 8—Glasgow Corporation Tramways), to which they are secured by oak pins. These chairs are either spiked to the transverse sleepers or imbedded in concrete, as is the case on the Wirral tramways.

Fig. 7 represents the section of the North Metropolitan tramways as relaid in 1877, when the cross sleepers were removed and tie-bars substituted for them, the longitudinal sleepers being imbedded in a shallow trough of fine concrete, and protected at their joints by a fir plate.

Mr. Deacon's system of tramway, as adopted by the Liverpool Corporation, is far more elaborate in its design than the London lines. On the inner circle, with which all the suburban lines are connected, the section of rail used (Fig. 9) has a central groove to take the central-flanged car-wheels. On the reconstruction of this tramway in 1875 the entire surface of the roadway was excavated to a depth of over 12 inches, and a bed of Portland cement concrete spread over its whole width, upon which the longitudinal sleepers were laid. The method of fastening is by means of two vertical holding-down bolts, placed at intervals of 3 feet apart, which meet in, and are secured by, a right and left hand adjusting nut. The top bolt is provided with an eye, which embraces a horizontal pin passed through the fangs of the rail, while the lower one penetrates some inches into the concrete, and in order to obtain more bearing surface is furnished with a cast-iron washer 6 inches in diameter.

For suburban lines Mr. Deacon uses a different section of rail, with a wide central web under the groove. This is fastened by vertical bolts, held down in the concrete by jaw washers, and secured in the groove by means of phosphor-bronze nuts. The weight of the suburban rail is 42 lbs., while that on the inner circle weighs 61 lbs. per yard.

In 1876 Mr. Robinson Soutar patented a system of tramway, the rail of which (Fig. 10) has its fangs indented $\frac{3}{8}$ inch, so as to allow the dogs to flush with the side of sleeper and rail. Mr. Soutar's lateral sleeper is of a trapezoidal form, and it is claimed that there is no possibility of the concrete falling away from its bevelled sides.

The first tramway constructed with metal bearings was laid in Buenos Ayres in 1870 by Mr. James Livesey, on a system patented by him in 1869. Livesey's steel rail, weighing 40 lbs. per yard (Fig. 11), differs from the ordinary box section in that it is hollowed out under the tread, and that the fangs taper towards the root, thus forming a dovetail with the step of the chair. The chairs are of cast iron, placed 3 feet apart, and are bolted in pairs to a bent wrought-iron sole-plate 4 feet 6 inches long, 5½ inches broad, and ¼ inch thick. The rails are tied down by wedge keys driven between the fang and the chair step. At the joints a double chair is used, to which the rail ends are bolted. The total weight of metal per mile of road on Livesey's system, including tie-bars and fastenings, is 112 tons.

The next system of metal way patented in England (though neither this nor Mr. Livesey's has been laid in this country) is that of Mr. Cockburn-Muir, which he terms his "Block Sleeper" system, and has also adapted to the use of light railways with double-head rails. The section of rail used (Fig. 12) is of the central-web or T type, and has rolled on the one side a fillet which fits into a corresponding groove in the chair, to which the rail is tied by a cast-iron key of the same length as the block, which also serves to fish the joints. The blocks are of cast iron, of an oblong form, their top surfaces lying flush with that of the rail and paving, and, being chequered, act as setts. They are cast hollow, and, being filled with gravel, are laid either upon the surface of the excavation or upon a prepared bed of concrete, at intervals of 3 feet 6 inches from centre to centre, the actual span between each being 2 feet 7 inches. The total weight of metal per mile, with iron rails at 30 lbs. per yard, is about 112 tons. The calculation of these quantities, as well as of those on Livesey's system, is based upon the South American lines, but there can be little doubt that for our heavy English lines the weight of material would have to be greatly increased.

The cast-iron tramway (Fig. 13) patented by Messrs. Ransomes and Rapier was specially designed to meet the requirements of heavy traffic, and has been laid in Glasgow Harbour. The blocks, which are cast in lengths of 5 feet, having the upper surface chilled and corrugated, rest upon a strong bed of concrete, with which material they are likewise filled. The weight of the blocks amounts to 319 tons per mile. A somewhat similar rail is laid in Newcastle Harbour, being, however, of an H section. The Newcastle rail is cast in 9-feet lengths.

In 1872 Mr. Kincaid took out the first patent for his system

of "Improved Permanent Way for Tramways," and shortly afterwards laid a short piece of road in Leeds as an experiment. This was soon followed by the Sheffield tramways, constructed in 1873, since which time the system has gained such popularity that at the present time it is laid in fourteen towns in England besides in Australia and other places.

Various alterations and improvements have been made since the first patent was granted, and the present mode of construction may be described as follows:—The rails are either of the double-flanged (Fig. 16) or central-web section (Fig. 17). The box rail is rolled with a groove and corrugated guard, but is arched underneath the tread, whereby an important saving of metal is effected without sacrifice of strength. The tread is flat, but inclines slightly towards the centre of the rail, so that the contact with the car-wheel is concentrated at its inner edge; the side of the groove next the tread tapers $\frac{1}{8}$ inch only, and the other side $\frac{9}{16}$ inch. The width of the rail is $3\frac{1}{2}$ inches, and its depth $2\frac{5}{8}$ inches, the thickness of the metal being $\frac{11}{16}$ inch under the tread and $\frac{9}{16}$ inch under the groove. This rail rolled in steel weighs about 47 lbs. per yard. It rests upon cast-iron chairs, the step of which is moulded so as to correspond exactly with the under surface of the rail, which bears equally upon it. Through the step there is a hole, into which is driven an hexagonal ash plug, tapering from $1\frac{3}{8}$ inch to $1\frac{1}{8}$ inch, the ends of which are sawn to the same angle as the sides of the step with which they lie flush. The rail is tied down to the chairs by means of short chisel-pointed spikes or pins, which are driven into the wooden plug through holes in the fangs. The bearing surface of the chair and rail is $3\frac{1}{2}$ inches long, except at joints, where a double chair 7 inches long is used, to which the rail ends are either fastened by use of two ash plugs and pins or by bolts. Underneath the fangs, but not near enough to touch them, the chair is widened so that its vertical sides are flush with those of the rail. The base of the chair is rectangular, and measures 14 inches by 12 inches and $\frac{3}{4}$ inch thick. The chair is cast hollow, with an opening at each end to enable the concrete to bind through it. The foundation is formed by excavating holes at intervals of 3 feet to centres 16 inches long by 18 inches wide. These holes are filled with lime concrete, which forms a solid block (the depth of which varies according to the nature of the traffic), and into which the chair is firmly imbedded (Fig. 15). A trench of concrete, $3\frac{1}{2}$ inches wide, is laid under the rail between the chairs, and serves to preserve it from the action of water. A bed of fine

gravel is then spread over the whole surface of the permanent way, on which are laid the paving setts. The single-web rail designed for this system weighs 45 lbs. per yard in steel. Its upper surface is exactly similar to that of the box rail; the central web is $1\frac{3}{4}$ inch deep, and tapers from $\frac{5}{8}$ inch to $\frac{7}{16}$ inch, the entire depth of the rail being $3\frac{1}{4}$ inches. The fastening of this rail is effected by wrought-iron keys instead of by pins and wooden plugs. The 45-lb. section shown in the diagram (Fig. 17) is considered strong enough for heavy street lines, although it has been rolled as heavy as 50 lbs., while for suburban lines its weight may be decreased to 40 lbs. per yard, or less. For roadside tramways, where no groove is necessary, Mr. Kincaid recommends a plain T head rail, which, with a head $1\frac{3}{4}$ inch wide, would weigh 29 lbs. per yard only, its entire height being $3\frac{1}{8}$ inches. An extension of the Bristol tramways was constructed with the central-web rail, and, as a protection against the heavy street traffic, concrete was laid, not simply under the rails and chairs, but across the entire width of the permanent way. A special chair has lately been designed to meet the requirements of exceptionally heavy traffic, and to give a uniform and solid bearing for the paving stones adjoining the rails. The base of this is much longer than that of the ordinary chair, and its weight is increased to 104 lbs.

With rails at 47 lbs. per yard, and intermediate and joint chairs weighing 45 lbs. and 60 lbs. each respectively, the total quantity of metal required for one mile of road on Kincaid's system may be estimated at about 161 tons.

The Manchester Corporation tramways were constructed in 1877 by the Borough Engineer, Mr. Lynde, on Barker's patent system, and since that time it has been applied to some of the suburban lines. The section of the rail (Fig. 14) is somewhat similar to that described in the foregoing system, is 3 inches wide, and the same in depth. The tread is $1\frac{1}{2}$ inch wide, and is curved to about 6 inches radius; the side of the groove adjacent to it is vertical, and the guard is not corrugated. The under surface of the rail is longitudinally indented on either side, and rests upon the cast-iron sleepers, which are moulded to correspond with it. The sleepers in this system are cast hollow, the base being 12 inches wide, and the length 2 feet $11\frac{1}{2}$ inches, the rail bearing over the whole of this length. The thickness of metal in the vertical sides of the chair is $\frac{1}{2}$ inch, and in the flanges tapers from $\frac{5}{8}$ inch to $\frac{3}{8}$ inch. The rail is secured by wrought-iron keys. A distance of $\frac{1}{2}$ inch only is allowed between each chair, by which means is obtained an

almost continuous support, which may be considered the distinguishing feature of this system. The hollow is filled with rough mortar, upon a bed of which, of 1 inch in thickness, the base of the sleeper rests. For sharp curves the sleepers are cast in shorter lengths, so as to avoid the necessity of curved patterns. The rails before being fastened are coated on their under surface with gas tar. A 2-inch bed of fine gravel is spread over the whole of the way, on which are laid the setts, which in Manchester are grouted with pitch and creosote. The total quantity of metal required per mile of Barker's road is about 280 tons. For suburban lines Mr. Barker uses a lighter rail, $2\frac{3}{4}$ inches wide, with $1\frac{1}{2}$ inch tread, weighing 34 lbs. per yard. The weight of the sleeper is likewise decreased from 137 to 90 lbs.

The system of tramway used in Nottingham is that patented by Messrs. Winby and Levick, who term it their "Continuous Girder System." The Nottingham steel rail (Fig. 18) is of a high flange or girder type, the groove being formed during the process of rolling. It is 6 inches in height, $2\frac{7}{8}$ inches in width across the head, with $1\frac{5}{8}$ inch tread, and $3\frac{1}{2}$ inches across the flange. The web is $\frac{3}{8}$ inch thick. This rail is secured to a continuous sole-plate 12 inches wide by $\frac{1}{4}$ inch thick by means of cotter bolts, care being taken that the rail and sole-plate shall always break joint. Tie-bars of wrought iron, screwed at each end, are used to preserve the gauge; these pass through the web of the rail, and are fastened with locking-nuts. The joints are fished in the ordinary manner with curved fish-plates 18 inches long. The base-plate rests upon the floor of the excavation, the setts next the rails being supported by it; and the space between the rail and setts filled with concrete. The weight of the steel rail per yard is about 70 lbs., and that of the wrought-iron base-plate $30\frac{1}{3}$ lbs., the necessary material for one mile of road, including bolts and fish-plates, would therefore amount to about 173 tons.

A portion of the Edinburgh tramways was relaid last year with a girder rail designed by Mr. Gowans, which is very similar to that of Messrs. Winby and Levick. In Gowan's rail, however, the head was rolled solid and the groove planed out. In this system no base-plate is used, and its chief characteristic would seem to be that at short intervals large quatrefoil holes are punched in the web of the rail, in order to enable the concrete to bind through it. Gowan's patent gives the saving of metal as a reason for punching these holes in the rail.

Although several patents have been granted for reversible

tramway rails, the only system in use in England is that of Messrs. Aldred and Spielmann (Fig. 19), on which several miles of road have been constructed by the London Street Tramways Company. This system can scarcely be classed among those consisting of metal alone, as in most cases the chairs have been laid on wooden transverse sleepers, although wrought-iron cross sleepers have also been used. The rail is rolled in two halves, both of which are reversible. The form of the tread and groove may be altered to the requirements of the line. This double rail rests in cast-iron chairs placed 3 feet apart, and is secured by wooden keys. The chairs are fastened with wood screws to the lateral sleepers. The weight of the rail is 63 lbs. per yard, and that of each chair 27 lbs. The total weight of material per mile, exclusive of timber sleepers, is about 145 tons.

Several other systems of tramway have been patented, but the time allotted to this paper necessitates the writer confining himself to the description of those only which have already been laid in this country.

The ideal of a modern tramway is a rigid rolling surface, calculated to reduce the tractive resistance to a minimum, and at the same time to offer no obstruction to the ordinary traffic. That this is possible there can be but little doubt; that such a pitch of perfection has been reached can scarcely be said of the majority of our lines, if of any. It is essential that the rolling surface should be flush with the level of the roadway, and the paving quite impervious to water. To ensure this the foundation must necessarily be firm, as otherwise no reliance can be placed in the strength and durability of the superstructure.

In considering the question whether the rolling surface should be elastic or practically inflexible, it should be borne in mind that the same conditions do not exist in a tramway as in a railway, the difference not only in the weight of rolling stock but also in the speed being so great, and as the Board of Trade will not allow a speed exceeding eight, or at the most ten miles per hour, the necessity for an elastic rail does not arise; the only plan likewise to prevent the water from entering the joints of rail and setts is to make the rail rigid.

Where concrete is used (and, now that there is every hope of locomotives being permitted to run on tramways, this will be necessitated on most lines) many failures may be attributed to the fact that the setts have been laid before the concrete has had time to set thoroughly, and the result is therefore an unequal road. There can be no doubt that whenever possible the best plan in constructing a tramway would be to excavate

and lay a solid bed of concrete over the entire width of the street, as was done in Liverpool, where the concrete was allowed ten days to set before the paving was laid. This, however desirable, is a costly arrangement, and one which can scarcely be hoped for under ordinary circumstances. The concrete should, however, be laid across the whole permanent way, and extend for at least 18 inches outside the rails. By this means many of the objections now urged against tramways may be removed, as it will generally be found that it is the paving and not the rail which sinks. The traffic is always much greater on the setts next the rails than on any other part of the road, and various arrangements have been made by which these are supported by the bearings of the rail. It is, however, open to doubt whether (with the exception of lines in streets where the ordinary traffic is of an unusually heavy character) the concrete bed is not strong enough to resist this extra pressure, if it is only properly constructed. The bed of gravel or sand should be no thicker than is necessary to bed the setts, its object being not to act as a drain for the removal of water, which should in no case be permitted to enter the joints of the paving, but simply to preserve the level of the roadway, and give a uniform bed for the granite setts, which would not lie evenly or solidly upon a level surface. In crowded thoroughfares the setts adjacent to the rails should be laid directly either upon the flanges of the chairs or sleepers, as in Manchester, and with Kincaid's heavy-traffic chair, or upon the concrete without the intervention of a gravel bed. To do this they should be carefully dressed and accurately fitted, as was done in Liverpool, by which means they form with each other a continuous surface. The rail should be quite independent of the paving setts, for the preservation both of its gauge and vertical position, its bearings being so firmly fixed as to need no extraneous aid for this purpose. This can be effected by imbedding the bearings in solid concrete, which should render the use of tie-bars unnecessary. The rail itself must be sufficiently strong to withstand all shocks to which it may be subjected, not only from the tramcars, but also from the ordinary street traffic. The box section generally used for tramways is of course much weaker than a Vignolles rail of the same weight, the proportion of resistance to pressure between them being about 1 to 2. From tests made at various works, the writer calculated that the ordinary 54-lb. box rail rolled in steel will safely withstand a weight of 6 tons for five minutes in the centre between 3-feet bearings without permanent set. The same result is obtained

from Kincaid's steel rail of the double-flanged section, which weighs only 47 lbs. per yard, or 7 lbs. per yard lighter. This seems to prove that the hollow under the tread strengthens rather than weakens the rail. Both rails on being tested to 7 tons showed a permanent set averaging $\frac{1}{25}$ inch, but in actual practice neither would ever be subjected to such a severe test as this, as the 54-lb. rail is supported throughout its whole length by the longitudinal timber, while the actual distance between the chairs in Kincaid's system is 2 feet $8\frac{1}{2}$ inches. With a central-web section of rail, additional depth and a corresponding increase of strength are obtained, and the rail laid in Bristol, which weighed 50 lbs. per yard, and was $3\frac{1}{4}$ inches in depth, was found to withstand as much as 13 tons pressure on 3-feet bearings without permanent set. The central-web rail laid in Manchester, weighing 40 lbs., tested by the writer at Barrow Steel Works, set 0·03 inch under $3\frac{1}{2}$ tons on 3-feet bearings. This may be accounted for by the fact that the greater part of the metal is contained in the head of Barker's rail. A central-web rail, such as designed by Mr. Kincaid for suburban lines, rolled without the bevelled under surface, and being $3\frac{1}{8}$ inches high, may, however, be safely estimated to withstand over 5 tons between 3-feet bearings without set. The proprietors of Wenby and Levick's patent claim for their rail that it will withstand 30 tons on above bearings without set; the writer has not tested any rails of either this or Gowan's system. The double rails of Aldred and Spielmann, tested by Mr. Kirkaldy on 3 feet 6 inch bearings, were found to set $\frac{1}{25}$ inch under a weight of 10,000 lbs. Upon 3-feet bearings it would take 16,000 lbs. to obtain the same result, and this rail may be assumed capable of withstanding a weight of about 7 tons without any permanent deflection.

In deciding upon the nature of the bearings to be used, the question of cost has naturally to be taken into account, and it will be conceded that metal bearings are, apart from other reasons in their favour, cheaper than those of wood. Kincaid's and Spielmann's systems are the only ones with intermittent bearings in use in this country, and the first cost of these is of course less than that of continuous metal sleepers, such as are, for instance, laid in Manchester. Actual practice has proved that the maximum necessary bearing surface per yard is 2 square feet; this being obtained, it follows that a surplus is rendered practically useless, and serves simply to increase the weight of material used. The two chief objections to a continuous sleeper are, the difficulty of packing when required,

and, when of cast iron, as in Manchester, of obtaining an equal bearing for the rail over the whole of its surface, there being a tendency towards rounding or hogback in these sleepers unless very carefully moulded, combined with a great liability to twist in the central-web rail. The latter difficulty is materially increased in curves, unless the chair is moulded to the required radius, which up to the present time has not been done. The use of a reversible rail is an open question; many railway companies have abandoned the double-head in favour of the bull-head section, and the power of reversing the rail may be counterbalanced by its weight and first cost. One great objection to a reversible rail is removed by Aldred and Spielmann, whose rail is suspended in the chair so that the lower head cannot come in contact with and be injured by it. In the high girder rail there is a liability, when subjected to transverse shocks from heavy cross traffic, to cant, and thus throw the line out of gauge. This tendency is however decreased in inverse proportion to the width of the base, which fact has been taken into account in Levick's system, in which the rail is bolted to a 12-inch sole-plate. In such a rail, also, the weight of the car overhangs the point of support, which may have a tendency to twist the rail, or even in Gowan's system, where the web is so weakened by the large holes punched in it, to break it. It is also doubtful whether a perfect joint can be obtained between the concrete and the rail so as to prevent the entrance of water, the effect of which is to produce a much more rapid corrosion upon steel than upon cast iron.

The side-dog now generally used for wooden sleepers is the most effective and simple form of fastening; it is, however, not applicable to metal ways. Iron fastenings bearing upon metal surfaces have a great tendency, unless accurately fitted, to get loose, and therefore in using wrought-iron keys the bearing surfaces of both rail and chair should be smooth-filed. The difficulty is obviated in Kincaid's system by the use of the ash plug and pins, and in Aldred's by the wooden key. In the systems laid in South America by Livesey and Cockburn-Muir, the rail is not punched, and this, especially with steel rails, the skin of which should never be broken if possible, may be considered a great advantage; in Cockburn-Muir's system, however, the rail has to be slid on and off the chairs, and its removal would therefore be attended with considerable difficulty and loss of time.

DISCUSSION.

Mr. H. L. Bucknall said, that he had hoped that a letter which he had addressed to Mr. Wilkinson Jones, on the subject of glass sleepers would have been included in the paper. A sample of the sleeper was lying on the table. The letter referred to a paper which had been read by Mr. Wood of Middlesboro' before the Iron and Steel Institute at Liverpool, in which the writer gave some particulars with regard to hard tempered glass sleepers. Since Mr. Wood's paper was read, he (Mr. Bucknall) had received a number of longitudinal sleepers of the same dimensions as those described by Mr. Wood. They were for the London Street Tramway Company, and samples had been tested by Mr. Kirkaldy. A sleeper 36 inches long supported at 30 inches, gave 7½ tons transverse resistance with considerable deflection before giving way. This proved material progress in manufacture, the first samples having given only about five tons. He was hence led to expect very great strength from glass for other purposes, but for all the purposes of a tramway sleeper no greater strength was required. He had also succeeded in producing several forms of railway sleepers. The tramway sleepers to which he had alluded had been put down in the Hampstead Road, opposite Frederick Street, and appeared to be satisfactory in every way. In fact, with regard to this length of road, the opinion given by the engineer of the North Metropolitan Tramway Company, in the discussion of Mr. Wood's paper, might be of value; he said that he could perceive no difference between that portion of the road laid with glass sleepers and those portions laid in the ordinary way. He (Mr. Bucknall) might therefore claim to have produced a reasonable new tramway sleeper. Almost any form could be moulded and tempered, and the cost of the articles would be less than that of timber, when produced on a manufacturing scale from Siemens's continuous tank furnace in connection with the blast furnace. The spare gaseous heat and molten slag would be utilized by this arrangement, and the material produced would be imperishable, being subject neither to corrosion nor to decay. He believed that a reasonable demand would exist for the glass sleepers, and their cost would be much less than that of iron. The sleepers being carefully moulded to suit the rail, and being incompressible, very few fixings would be required. The fixing now used was a single band of iron, but no doubt a better form of fastening could be made, as the material was so tough that holes might be bored in it. His im-

pression was that tramways ought to be constructed of cross sleepers, with a good heavy steel rail. If the glass sleeper was used, the permanent way would be indestructible. Some experiments were made on toughened glass in Scotland. A plate $1\frac{1}{8}$ inch thick was tested with a falling weight of 900 lbs. It was allowed to drop only a short distance at first, and the height was gradually increased to 20 feet. A rail which had been placed on top of the glass was broken, but the glass itself was not broken.

Mr. HENDERSON said the experiments in question were made in his works at Irvine and in his presence, and he was extremely surprised to see the extraordinary elasticity and strength of the glass plates. They were put down in the usual way on a bed of 9 inches of ballast, principally composed of sand and ashes, immediately below which was a very hard road that had been made use of for the purposes of the works. The weight of 900 lbs. was first dropped from a height of $2\frac{1}{2}$ feet, and the fall was ultimately increased to 20 feet, which was as high as the shears would allow. The rail which was broken by the weight was an iron bridge rail, with a face of about 4 inches. The glass on which the rail rested remained intact. A thin sheet of wood, of $\frac{1}{4}$ inch thick had been interposed between the glass and the iron. A small common tramway rail of about 2 inches in section, such as was used for hand-waggons, was substituted for the large rail. The fall of 20 feet then broke the glass, but he was astonished to find that the glass did not smash into dust. It broke into only four or five pieces. A plate of cast iron, about half the thickness of the glass was subjected to the same test, and it broke at 10 feet. He was very much surprised to see how the falling ball rebounded from the glass. It jumped off in all sorts of directions, so that it was dangerous to stand near it. The slag from which the glass was produced abounded in unlimited quantities, and in Scotland there was an enormous quantity of waste gases which could be utilized to produce the necessary heat for the manufacture of the glass. Soda salts would be added to produce the requisite strength. He thought that by applying to this mixture Mr. Siemens's method of annealing, which was a sort of semifusion, they would be able to produce a material which would be extraordinarily cheap and which would be indestructible by wet or ants. In reply to Mr. Nursey the speaker stated that the falling weight was not allowed to come upon the sleeper without the intervention of the rail. It was thought necessary to place the iron rail and also a thin slip of wood upon the glass sleeper.

Mr. NURSEY said that it appeared that a packing of wood and an iron rail had been interposed between the glass sleeper and the ball; he thought that if the ball had been allowed to fall upon the unprotected sleeper the result would have been far different. He could not agree with the suggestion that glass sleepers should be applied to railways. Such an application would be an entirely retrograde movement, as the glass sleepers were very rigid. It would, in effect, be going back to the old system of the rigid stone sleepers which had for years been abandoned. The tendency of the present time was in the directions of wrought-iron permanent way, in which advantage was taken of the elasticity due to the arrangement of the parts.

Mr. HENDERSON said that he thought that all experimental chemists had satisfied themselves that glass was an elastic material. To his mind, the rebound of the ball showed the elasticity of the sleeper. If the ball had fallen on a stone it would have remained upon it.

The PRESIDENT said that Mr. Nursey had started the objection that the non-elasticity of glass rendered it unsuitable for tramway sleepers. But there was no doubt that there was a wide field for the application of the slag from iron furnaces; and they, as engineers, ought to hail anything in the way of a possible economical application of that which had hitherto been a waste material, and, indeed, a nuisance.

Mr. HENRY ROBINSON said that he was under the impression that experiment had proved that glass, when exposed to vibration, became changed in its molecular structure. He believed that this was found to be the case with glass sleepers some years ago. He should like to know whether any recent experience had confirmed that observation.

Mr. KERSHAW said that he had not heard the writer of the paper describe any plan for connecting the ends of the rails of tramways. On the North Metropolitan system, the absence of fish-plates, or other method of joints, left the ends of the rails free to move up and down, which led to the more rapid destruction of the permanent way. The rails getting loose, also caused the cars to jolt, and did injury to the rolling stock besides. The rails became loose in the tramways laid down in London whether they were spiked or screwed to the sleepers. He believed that the tramways would keep in much better repair if the ends of the rails were fished or dovetailed together.

Mr. ALFRED WILLIAMS said a tramway was laid down in the Brixton Road, and all the rails were fished, of which plan he approved. With reference to all the existing tramways which

he had seen, they appeared to be entirely deficient in drainage. He believed that this defect was the cause of the failure of every tramway. The rails sank and the water flushed up between the stones and metals, and thus loosened the materials of the roadway. The roads ought to be made in a curved form, so that the water might drain away.

Mr. Grainger said that he was sure that they were all extremely obliged to Mr. Jones for his admirable paper, but he had omitted to mention the one great evil and drawback of the present system of constructing tram lines, and that was the skidding of the wheels against the rigid tram lines. He (Mr. Grainger) had on the table three models showing modifications of a patent which he had taken out for remedying the defects of the present system of tram rails. In two of the modifications he dispensed with fish-plates by abutting the ends of two rails together, and placing or setting them on a chair; then a steel clip or cap, having wrought staples, was placed on each side, and into the staples one oak or larch taper key was inserted and driven home on each side, and thus the rail and clips were securely fastened to chairs without the use of fish-plates, bolts, &c. To deaden the sound, he placed between the tram rail and chair a layer of felt. The anti-lapses or non-skidding blocks could be applied to any existing tram line, and would save enormous expense in repairs alongside the rails which now was constantly being incurred. When the rails were placed or butted together, the non-skidder blocks or caps were placed in position, and so they clipped and held the rail without the presence of either fish-plates, bolts, or nuts. That system was about to be used in London. He believed that he was right in stating that there were upon an average ten actions at law each day against one of the large London companies resulting from the breaking of axletrees, springs, and wheels, caused by vehicles skidding along the tram rails. If each action cost only the moderate sum of 3*l.* there would be thus an amount of 30*l.* a day paid in legal expenses, which ought to be applied in the shape of an increased dividend, and which actions arose wholly and solely from the ruts which formed alongside the tram rails, and thus damaged a vast number of vehicles attempting to cross the tram lines in an oblique direction. One radical fault in the present mode of construction where wood sleepers were used was that the wood was laid horizontally so that the wet or moisture could not escape, and which was contrary to the ordinary growth of the tree. It would be more suitable and be far more lasting if it was

placed vertically on the concrete. Besides dispensing with fish-plates, another great feature in his modification was that he dispensed with cross-tie rods, as on the under side of the rail he rolled a rib or fillet, which fitted into a corresponding groove in the chair, so that when the rail was set upon the chair no lateral strain, however great, would move the rail out from its gauged position. The cost per mile was about 4000*l.* where the anti-skidding blocks were placed 6 inches apart, but it was more if they were closer; that price included the concrete 6 inches deep by 8 feet wide, or 784 cubic yards, and paving 4675 super yards. The rails ranged in his various systems from 36 lbs. a yard and upwards.

Mr. H. P. Stevenson said that if he had a tramway to carry out, he should like to have a good breadth of base, as few parts as possible, and a good heavy rail. Speaking as one of the public, he regarded tramways as intolerable nuisances, but he quite admitted the convenience to travellers. He should like to know from the reader of the paper whether he had had any experience as to the wear and tear of the different systems. That information would guide them very much in judging of the advantage or disadvantage of any particular system. He held that it was a very advantageous thing to have the granite setts close up against the rails to support them, and he considered that granite was the proper material for the pavement in connection with a tramway, although it was objected to by some persons on account of the noise of vehicles passing over it. He should like to have information as to the durability of various kinds of pavements in connection with tramways, such as granite setts, wood, and asphalte.

Mr. Baldwin Latham said that glass sleepers had been put forward by some of the speakers as capable of bearing an immense amount of percussive strain, but really, when the matter was inquired into, if the amount of force which was used in the tests was calculated, it would be found that it was not very great. The difference in the force of percussive action between a fall of 2½ feet and a fall of 20 feet, with a weight of 900 lbs., falling upon a rail, would not be greater than the proportion of 1 to 3, and regard must be had to the fact that the glass sleeper was protected by a slip of wood with the iron rail on top of it. It was well known that if a mass of metal or other material were placed to receive the impact of a blow, percussive action was not transmitted. A well-known exhibition at fairs was based on this fact, for he had seen a man lie down and have a large stone put on his chest, and another man break the stone with a sledge hammer. It was quite clear in

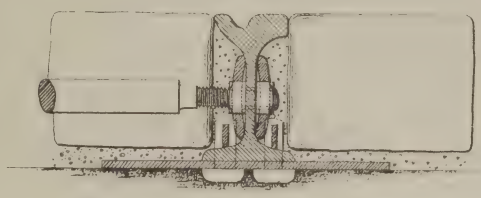
this case that percussive action was not transmitted, and the experiments that had been referred to only showed to a scientific man what little value could be placed upon them. There could be little doubt that a mass of metal weighing 900 lbs., falling from a height of but 2½ feet upon an unprotected glass sleeper such as had been described, would have very soon destroyed it. Until a more scientific way of testing glass sleepers was resorted to, and the article was shown to stand the tests to which it was submitted, it was quite clear that no confidence could be reposed in them.

Mr. Wilkinson Jones, in reply, said that he had listened with great pleasure to the discussion. Mr. Kershaw had asked a question about fish-plates. He (the author) had mentioned a fish-plate in the paper, namely, that designed by Mr. Kincaid for the Gothenburg tramways, consisting of an inverted channel with holes in the sides coresponding to those in the rails. In most metal systems the joints were fished by the chair itself. There was formerly a fish-plate used in conjunction with the vertical spike, but since the use of this has been abandoned, the only method of getting over the difficulty where timber sleepers are used seemed to be to use the channel plate. An allusion had been made to drainage. He had not said much on that subject, being of the opinion that no water should be allowed to get below the surface. He was sorry to say that he could not, as desired by one speaker, give any comparison of the wear and tear of different systems, as his experience had been more with the manufacture of the material for tramways than with the maintenance of the roads themselves.

The President, in closing the meeting, said that he was sure that they were all very much indebted to Mr. Wilkinson Jones for his able paper, and for the very interesting discussion which had grown out of it. He (the President) sympathized very much with Mr. Stevenson in his strong common-sense remark that the value of one system over another must depend not on its first cost, but on the cost of maintenance. This was an obvious truism, and nothing but experience would lead to any reliable conclusion on that point. Mr. Stevenson, speaking as one of the public, had expressed an abhorrence of tramways generally, but he (the President) found the tramway car an exceedingly pleasant place in the city of Turin in August last, when the thermometer was somewhere about 90° in the shade, and walking was very unpleasant. The Italian tram cars had enabled him to see nearly the whole of the city of Turin for the small sum of sixpence. Damage was done to wheels, axles, and springs of vehicles by tram rails, but he was

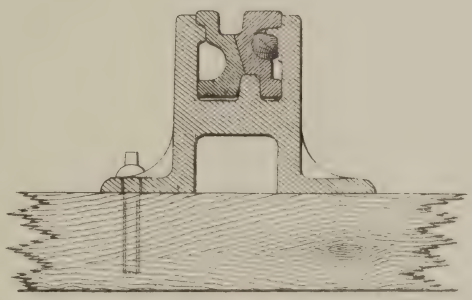
not sure that the fault rested exclusively with the tramway people. It might be on the part of the paviors, who were not perfect in the art of accommodating the roads to the lines which were laid upon them. He thought that engineers had something to learn in that respect. Mr. Stevenson was in favour of granite. He (the President) would be in favour of anything that would last a long time and keep the water out. A sloppy rail was not necessary. They must all hope that the time would come when the tramway system would be free from the objections which had hitherto prevailed.

Fig. 18.



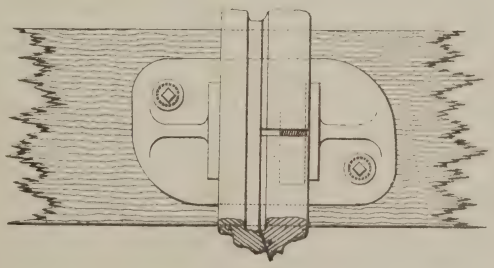
Winby & Levicks System.

Fig. 18.



SECTION.

Aldred & Spielmann's System.

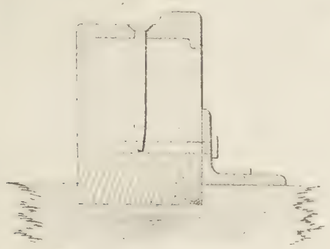


PLAN.

Fig. 1.

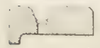
New York & Haarlem

Fig. 2



Trams Step Rail

Fig. 3



Birkenhead Rail

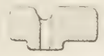
Fig. 4

Noble's Crescent Rail.

Fig. 5.

London Tramway's First Rail.

Fig. 6.

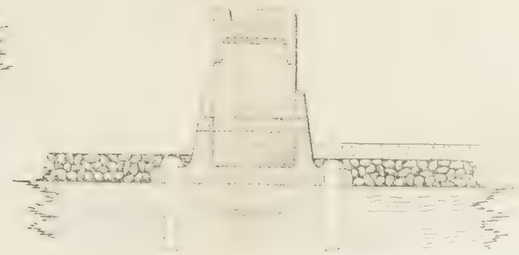


Glasgow First Rail.

Fig. 7

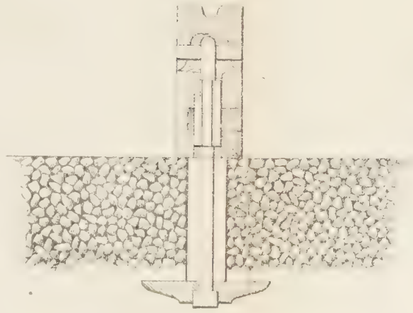
North Metropolitan present Construction.

Fig. 8.



Glasgow – Present Mode of Construction.

Fig. 9



Deacon's System.

Fig. 10

Fig. 11

Soutar's Rail

Livesey's System

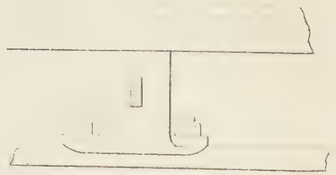


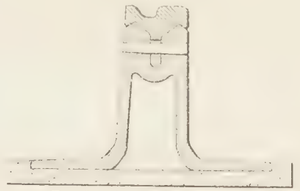
Fig. 12

Cockburn – Muir's System.

Fig. 13

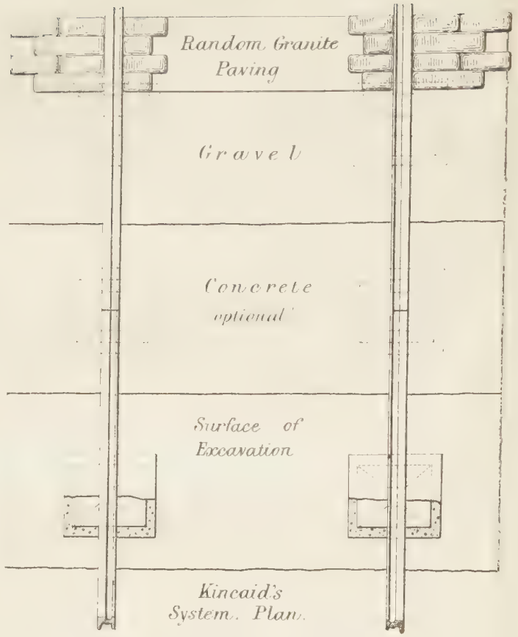
Ransome & Rapier's System.

Fig. 14.



Barker's System.

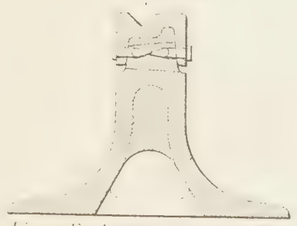
Fig. 15.



Kincaid's System. Plan.

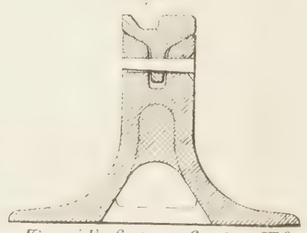
Scale 3/8 Inch = 1 Foot.

Fig. 16



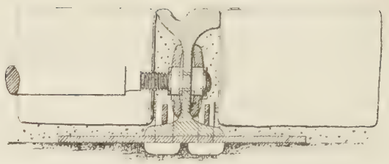
Kincaid's System Section No 1.

Fig. 17



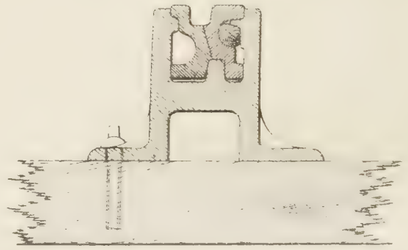
Kincaid's System Section No 2.

Fig. 18



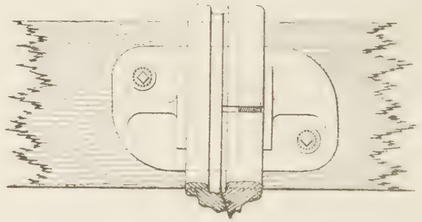
Winby & Levicks System.

Fig. 18.



SECTION.

Aldred & Spielmann's System



PLAN.

Scale 1½ Inches = 1 Foot.

E. & F. N. Spon, London & New York.

December 1*st*, 1879.

ROBERT PAULSON SPICE, President, in the Chair.

SEWAGE DISPOSAL.

By Henry Robinson.

The question of how the sewage and refuse of our towns can best be disposed of is one which yearly increases in interest as the evil consequences that attend the neglect of the subject are more and more realized, and the necessity for proceeding on sound principles, both from economic and sanitary considerations, is better appreciated. The importance that this branch of our profession has of late years acquired in public estimation involves a duty on the part of those who are called upon to advise on it to study impartially the accumulating mass of information which is now available, and to form opinions based on experience and accurate practical observation. The removal of fœcal matter from towns is, broadly speaking, accomplished in one of two ways. First, by the water carriage system; secondly, without a system of sewers, such as by the pail, and dry earth methods. The retention of the fœcal matter for even a short time in pails or tubs in the dwellings, however carefully the system may be administered, involves a risk of nuisance, and a further objection in the visible removal of it. Perhaps this is partly sentimental, but the removal from a house in pails or tubs of the fœcal matter produced in it appears to be hardly in accordance with the civilization of the period; and considering that a system of sewers is necessary, even where the pail method is employed, the adoption of it means duplicate systems for getting rid of the refuse from the houses, the economy of which is open to grave doubt except in cases where an ordinary system of sewerage is inapplicable.

The water carriage system is a necessity in order to effect the removal of the slop water and fluid refuse, which cannot be got rid of by receptacles for fœcal matter. After a system of sewers has been carried out in a town, it appears natural that it should be utilized to enable the excrementitious matter from houses also to be conveyed away by it. Although a

sanitary authority may discourage the water-closet system and the connection of closets with the sewers, it cannot, the author thinks, legally prevent the connection being made. In the course of time, even where the pail system existed, it is probable that, as the inhabitants experience the convenience of the water carriage system, they may insist on exercising their right of resorting to the sewer to get rid of their water-closet refuse. The exclusion of the fœcal matter does not deprive the water-carried portion of sewage of its polluting properties, so as to enable it to be discharged into streams and watercourses without contravening the Rivers Pollution Prevention Act. It has been ascertained that 12 tons of average sewage from a midden and privy town will, in round numbers, equal 10 tons of sewage from a water-closeted town in manurial value, so that the exclusion of water-closet refuse only reduces the manurial strength, and consequently the polluting capacity of the sewage, by one-third.

Rochdale, Salford, and several other towns have resorted to the pail system, but it is not possible to regard the subject *per se*, as it is necessary to include with it the general scavenging of the town, as well as other supplementary arrangements for removing refuse, all of which are factors in considering the financial question. Manchester has partially adopted the system by converting as much as possible of the town refuse into concentrated manure, at a cost of about 80,000*l.* for works to deal with the refuse of one-half the city. The greater part of the material brought to the works is made into manure, mortar, or fuel, to accomplish which about 1500 men are required, with 300 horses, 400 vehicles, including 120 railway waggons. At these works about 11,000 tons of concentrated manure it is estimated will be produced annually.

The systematic removal of refuse and its disposal in this way is preferable from a sanitary point of view to its being allowed to accumulate in cesspits, and this has been proved to be the case by the improved health returns from the districts operated upon at Manchester. The financial results must, however, be considered in conjunction with what has to be arranged in order to dispose of the rest of the refuse; and although much has been published and advanced in advocacy of the system, the author is unable to accept a great deal that is asserted in its favour.

The following is the mean of analyses of a gallon of sewage by Letheby, Hoffman, Witt, Way, and Voelcker:—Organic matter, 27·72 grains; nitrogen, 6·21 grains; phosphoric acid, 1·57 grains; potash, 2·02 grains. Dr. Letheby arrived at the

conclusion that 1000 persons of a town population contributed 3750 gallons of sewage a day, containing about 167 lbs. of organic matter, 33·3 lbs. of nitrogen, 9·4 lbs. of phosphoric acid, and 6·9 lbs. of potash.

The necessity for promptly removing the excreta and refuse from the neighbourhood producing it will be readily conceded, but it too frequently happens that from one cause or another, such as insufficient velocity, want of flushing, "dead ends," and defects in sewers, some of the refuse intended to be conveyed away is able to accumulate and putrefy. The emanations given off from foul sewers produce intestinal derangements, fevers, and other maladies. The late Dr. Herbert Parker observed that even when the gas was not perceptible to smell it was capable of producing diarrhœa and severe constitutional disturbances. The more acute diseases, such as typhus, typhoid, and scarlet fevers, are specially liable to be introduced into the system through the organs of respiration, and the germs of these diseases being passed into the sewers from infected houses may be conveyed to great distances and distributed over wide areas. The late Dr. Murchison stated that he had met with few examples of enteric fever which on investigation were not traceable to defective drainage. It follows, then, that where a sewerage system is not skilfully devised and carefully carried out it furnishes a ready means of creating and propagating diseases instead of preventing the possibility of their occurrence as was expected. The evils arising from defective drainage have been often urged, but too frequently they are either forgotten or disregarded. The sanitary authorities throughout the country are not sufficiently alive to the necessity that exists for enforcing the provisions of the Public Health Acts, and for seeing that the houses in their districts are in a proper sanitary condition; that they have no untrapped connection with the sewers, and that the house drains are so laid that the refuse from it is carried to the sewerage system promptly, and before decomposition arises. Also that the ventilation of both house drains and sewers is effectual. As the most carefully devised plans are liable to be frustrated by carelessness or scamping on the part of those executing the works, the author makes a rule in his practice not to allow any sewers, drains, or similar work to be covered up until a written certificate has been obtained to the effect that the work has been inspected and passed.

Although a great advance has been made of late years in the degree of attention which is given to house sanitation, it is nevertheless a fact that owing to the permissive nature of sanitary legislation, and to the ignorance or apathy of the

sanitary authorities, there is a great deal more preventable disease in the country than there ought to be. London does not escape from this implied censure on sanitary authorities. The vestries—which are the sanitary authorities for London, but are free from the control of the Local Government Board—seldom exercise the powers vested in them to overhaul the house connections, and to enforce a compliance with the rules which govern proper house drainage in connection with a system of town sewerage. Even where care is taken in regard to the removal of the refuse there is neglect in preserving the water supply from contamination. When it is supplied in a pure state by the water companies, it frequently becomes polluted before consumption by storage in cisterns which are not periodically and properly cleansed.

Public attention has of late been directed to the question of the water supply of London, and although the supply should be constant instead of intermittent, the chief causes of mischief appear to be overlooked. It is not the quality of the water supplied to the metropolis that is a factor in the death rate from filth diseases, but it is the indifference which is shown by the owners and occupiers of houses as to cleansing the cisterns and the neglect on the part of the vestries, whose duty it is to enforce the observance of all the well-known rules as to house sanitation. Clauses 82, 83, and 84 of the Metropolis Local Management Act of 1855 give power to the vestry to inspect the internal arrangements of houses, to require the occupier to rectify defects which are injurious to health, or in the event of his neglecting to do so the necessary work can be done and charged against him. There would appear to be no hope of progress being made in sanitary matters commensurate with the gravity of the subject until there is a more vigorous enforcement of existing sanitary legislation. It is the author's opinion that all matters relating to the health of the community would be better administered by a special department of health with a well-organized staff. The cost would be abundantly repaid in the saving of lives which are now annually sacrificed to filth diseases, and by preserving in good health the still larger number whose physical strength is impaired from the same cause.

Where provision can be made for excluding the bulk of the rain-water the expense and difficulties attending sewage disposal are reduced. The sewers then have to convey a more uniform volume, consisting of the fluid refuse from the houses without the addition of any but a small proportion of the rainfall. It must not, however, be forgotten, that the washings from roads

after a long drought are very foul, notwithstanding the most complete system of scavenging. The filth removed by rain from gutters and bye-streets is very great, and is practically sewage. Analyses of the water flowing in the London gullies after a heavy rain succeeding a dry period have proved it to be as foul as ordinary sewage, in regard to the amount of putrescible organic matter which it contains.

A second sewer is sometimes employed to carry off the rainfall independently of the refuse. Where there are two sewers special care has to be taken to prevent confusion arising between them, as workmen in connecting a house drain with the sewerage system might resort to whichever sewer happened to be the nearest. Where the separate system is adopted the second or clean sewer might advantageously be employed to lower the level of the subsoil water. Experience has proved the advantage to health that results from the subsoil being drained to a sufficient depth to preserve in a dry state the basements and surroundings of houses. Sometimes the foul sewers even are laid open-jointed in order that they may serve as drains for the subsoil as well as sewage carriers. This endeavour to combine two essentially distinct operations is, the author thinks, wrong in principle. The sewer itself should be made absolutely watertight, so as to prevent the escape of sewerage from it into the subsoil. The separate drain pipe should be the open-jointed pipe, and it could be laid in the same trench with the sewer.

Having collected the sewage into its main outfall, the next point to consider is how the sewage is to be disposed of. The Rivers Pollution Prevention Act of 1876, amongst other provisions, imposes on towns the duty of employing "the best practical and available means to render the sewage harmless" before it can be permitted to flow into any stream or watercourse. This Act has not been productive yet of the anticipated amount of good in regard to its application to town refuse and sewage. Towns which are carrying out, or are about to carry out a system of sewerage, have in most cases to provide some means of purifying the sewage, but they are confronted with the difficulty of ascertaining what will be recognized as a compliance with the Act. It was contemplated that certificates should be given to towns to the effect that they were dealing with their sewage efficiently. A strict technical compliance with the Act appears to be construed into its being necessary to convey the sewage for purification on land, so that those towns which are so situated as to be unable to dispose of their sewage on land could not obtain

the certificate if it were essential as a protection against litigation.

The advisers of sanitary authorities on sewage disposal feel that owing to the want of discretionary power on the part of the Local Government Board, the best practical means of purifying sewage can only be defined as filtration through land. Although this is admitted to be so where land can be obtained suitable for the purpose, yet there are numbers of towns where land cannot be obtained either of suitable quality or of sufficient quantity, or where a sewage farm is objectionable, and then the question arises as to what is to be allowed. It is a choice of evils, and the least evil in some cases is to employ chemical treatment as an alternative to land filtration, or as an adjunct to it.

Probably before long the Rivers Pollution Prevention Act will be amended so as to give greater latitude in regard to what will suffice to prevent towns from incurring the penalties recoverable for a non-compliance with the Act, or from incurring the expense of a system for attaining a degree of purity in the sewage effluent higher than need be. The standard of purity ought to be allowed to vary with the circumstances of each place. That fixed by the Rivers Pollution Commissioners, namely, 0·3 part per weight of organic nitrogen in solution in 100,000 parts by weight, is needlessly high where the sewage effluent is passing into a large stream.

The difference of opinion as to the required standard of purity of effluents, and the efforts sometimes made to compel authorities to incur the expense of obtaining land where it does not exist at a reasonable distance, causes many town authorities to do nothing. They are somewhat encouraged in this attitude by the singular exemption which was made in the Rivers Pollution Prevention Act in regard to the metropolitan sewage and the river Thames.

The Metropolitan Board of Works was created in 1855, for the purpose of sewering London and purifying the Thames. This duty was imposed on the Board at its formation, and it has fulfilled it to the extent of executing an admirable system of sewerage, with outfalls at Barking and Crossness. These are supposed to remove the sewage to where it no longer pollutes the river or the metropolis, but it is generally considered that a large portion of the sewage returns to pollute the river within the metropolitan area, and that the Board of Works has only partially accomplished the work for which it was specially created. In clause 3 of the Metropolis Local Management Act Amendment of 1858 it expressly states that the powers

conferred by the original Act of 1855 "shall extend and be applicable as well to works for deodorizing sewage." This clearly indicates that at that time it was contemplated to apply some treatment to the sewage at the outfalls before its discharge into the river.

The Conservators of the River Thames are supposed to have the power of preventing the Metropolitan Board from continuing this alleged pollution, but the powers of the Conservators as regards pollution appear, from their Act of 1867, to be confined to the preservation of the purity of the river to the western boundary of the metropolis. The Conservators have somewhat tardily taken action with respect to the outfalls under the 20th and 21st sections of the Thames Conservancy Act of 1870, on the ground that they have injuriously affected the navigable channel by the formation of mudbanks. These sections of the Act provide that any bank or other obstruction to navigation which resulted from the discharge of London sewage into the river must be rectified at the expense of the Metropolitan Board. This—it may be termed the commercial—part of the case is now being dealt with by arbitration, and the award of the umpire will be made in the form of a report to the Board of Trade.

It will be noticed that the sanitary aspect of the question is not gone into, the present inquiry being limited to whether the Board of Works or the Conservators are to bear the cost of dredging certain mudbanks. This arbitration will, however, doubtless influence the sanitary part of the case, but it would have been more satisfactory had the consideration of the question in its bearings upon the public health been regarded as of at least equal importance to the consideration of it in reference to any interference with the river bed. The dissolved and lightly-suspended impurities in sewage may float up the river as far as Richmond—as they are alleged to do—decomposing and polluting the air without adding a cubic yard to the banks or interfering with the channel, and yet infinitely more mischief might result.

It has been pointed out by Professor Stanley Jevons, with reference to the formation of sewage mudbanks in the Thames by the discharge of sewage at the Crossness and Barking outfalls, that matters which would remain suspended for many days in fresh water would be readily precipitated in a few hours when the water is saline, which it is at flood tide. He considers that much of the sewage matter would, if left to itself, float in water, but in the presence of saline matter cohesive attraction comes into play, and the minute grains of

suspended clay then adhere to the organic sewage particles and carry them to the bottom of the river.

The objectionable nature of the deposits in the Thames, whether due to the outfalls or not, has been observed by many chemists. The late Dr. Letheby described them as being composed of black and fœtid mud in a state of active putrefactive decomposition, and when examined under the microscope were found to consist of broken-up sewage matters, the remains of animalcules, the disintegrated tissue of vegetables, and swarms of diatomaceous remains. He stated that the mud and the suspended matters of the river contained from 6·3 to 18·9 per cent. of the solid constituents of sewage.

Of all the methods of disposing of the sewage of the metropolis at the outfalls, the one which, in the opinion of the author, is least likely to succeed is its purification on land. To enable it to be utilized on land an expense would have to be incurred in the acquisition of the enormous acreage—from 30,000 to 40,000 acres—required, as well as in pumping the sewage to a sufficient height to control this area, out of all proportion to the commercial results which are likely to be realized. No return can be expected from crops produced on metropolitan sewage farms to cover more than a small part of the cost of purifying the sewage on them. The sanitary requirements of the case will be fulfilled by applying a simple chemical deodorant and precipitant, avoiding an unnecessarily high standard of purity. A small area of land to filter the effluent, if a high standard is required, could be employed.

From calculations which the author has made he considers that the sewage of the metropolis could be dealt with by chemicals at the present outfalls for about 7*d.* per head of the population per annum, and the sludge produced converted into a portable manure weighing, in a semi-dried state, about 300 tons a day. This would be like farmyard manure, but rather more valuable. As it became appreciated it would realize a fair value, and would repay part of the cost of treatment.

The author does not propose to enter in detail into his views for purifying the sewage of London at the outfalls, as he is of opinion that the subject cannot be properly dealt with at a public meeting or in the course of a paper. It is partly a chemical and partly an engineering question, and should be made the subject of investigation when those competent to advise can be called in. Voluntary advice on the part of partisans of systems, whether patented or not, does not recommend itself as the most reliable way of arriving at conclusions. The several means employed for purifying sewage will next be

briefly considered, and its application to land will first be referred to.

Dr. Voelcker, in the 'Journal' of the Royal Agricultural Society, gives the following interesting conclusions respecting the absorption by various soils of ammonia—the most valuable constituent of sewage—and its salts. He states: (1) All soils experimented upon had the power of absorbing ammonia from its solution in water. (2) Ammonia is never completely removed from its solution, however weak it may be. On passing a solution of ammonia, whether weak or strong, through any kind of soil, a certain quantity of ammonia invariably passes through. No soil has the power of fixing completely the ammonia with which it is brought into contact. Thoroughly drained porous land, where it can be obtained, is the best way of purifying and utilizing sewage. It has the property of converting the nitrogenous organic matters in sewage into nitrates, which, however, are not stored up in the soil for utilization when required, but such as are not soon absorbed by vegetation pass through the ground beyond the reach of the plant roots. In other words, the fertility of land is not increased by applying larger volumes of sewage than the growing crops on the land can assimilate. This has been exemplified in the case of the Craigintinny sandy meadows near Edinburgh. Analyses of the soil after many years of continuous irrigation with large volumes of sewage show that it contained only about $1\frac{1}{2}$ per cent. of organic matter, which was due solely to root fibres. These sandy meadows, therefore, have not become converted into rich agricultural land, but remain nearly pure silica.

In a report to the Council of the city of Carlisle, by Mr. McKie, the city surveyor, some interesting particulars to the same effect are given as the result of experiments made by Dr. Walker of that town. Six samples of earth were examined, three being taken from land which had been for years under sewage irrigation, and three from land which had not been irrigated. The following are the average results from these experiments, the samples being taken from 1 foot to 3 feet from the surface:—

Irrigated Soil.	Per cent.	Non-irrigated Soil.	Per cent.
Organic matter, humus, &c.	3·4	Organic matter, humus, &c.	3·1
Ammonia	·016	Ammonia	·013
Organic nitrogen	·006	Organic nitrogen	·005
Nitrates and nitrites	trace	Nitrates and nitrites	trace
Phosphates	·016	Phosphates	·015
Chlorides	none	Chlorides	none

These observations show that there is practically no difference

between the composition of the irrigated and non-irrigated soils, the former being very slightly richer in the more insoluble substances contained in sewage; but the characteristic ingredients of sewage, namely, chlorides and nitrates, are conspicuously absent. It is therefore clear that the nitrogenous matters are either absorbed by vegetation or pass through the soil.

The conclusion to be drawn from these and similar experiments is, that however well land may act as a purifier of sewage for sanitary purposes, it can only be relied on to utilize the manurial constituents of the sewage according to the requirements of the crops for the time being assimilating them, and that any excess of the supply of manure over the demand by the crops is not stored up for subsequent use, but is, agriculturally speaking, wasted, passing off in the subsoil drainage either partially or wholly purified, according to the nature of the land and of its preparation to filter and oxidize the sewage passed through it. The author has tabulated the cost of irrigation at twenty-two towns in this country, and finds the averages to be as follows:—

Average flow in gallons per head of population, per day	39·3
Average number of population per acre of sewage farm	114
Average annual cost of sewage farm per head of population ..	1*s.* 10*d.*
Average annual cost of sewage farm in the £ of rateable value ..	6½*d.*

Where the most porous land can be obtained by special preparation, such as deep and close draining it, a larger volume of sewage than that from 100 people or thereabouts can be passed on to an acre. Where such is done, however, the land must be regarded solely as a filter to purify the sewage, and not as a means of utilizing it for agricultural purposes. At present there has not been sufficient experience gained on a large scale to determine to what extent a small area will continuously purify a much larger volume of sewage than has been stated. The author would not advise a larger proportion than the sewage of 300 people to an acre, and then he would require the special circumstances of porous land well drained to about 5 feet or 6 feet, and having a perfectly free outfall for the drains.

Where land cannot be obtained of suitable quality and altitude, it must be supplemented by chemicals where a small area of land only can be acquired, or be entirely replaced by chemical treatment where no land can be obtained.

Dr. Voelcker, F.R.S., in the 'Journal' of the Royal Agricultural Society of England, No. xxviii., states:—"Numerous experiments with all kinds of precipitating agents, and the

experience of others on a large scale, have led me to the conclusion that by far the most efficacious, and, on the whole, the most economical, precipitating agent is crude sulphate of alumina, assisted by the addition of just enough lime to render the effluent slightly alkaline, and to effect the complete precipitation of the alumina from the crude sulphate."

This is also the author's opinion, and it fulfils the conditions which his experience has led him to adopt, namely, that the precipitants employed should be both deodorants and disinfectants, and should be capable of effecting the clarification of the sewage without adding any material amount of solid matter to the sludge deposited from it.

The following is a brief reference to the most important chemical processes in actual operation:—The lime process is one of the oldest systems of treating sewage with chemicals, and is still in use in many places. From 1 to 1¼ ton of lime is required per 1,000,000 gallons of sewage, according to the flow and proportion to population. The quantity of sludge produced per day by lime treatment is about 7 cwt., containing 90 per cent. of moisture, or about 4 cwt., containing 50 per cent. of moisture, to each 1000 persons.

Scott's process has for its object the conversion of the sewage sludge derived from lime precipitation into cement by burning. For this purpose the sludge must contain a definite portion of lime. The Corporation of Burnley have adopted this process, and pay an annual subsidy of 6*d.* per head. The population of Burnley is 40,858. The number of water-closets is 900. The daily flow of sewage varies from 1,000,000 gallons in the driest weather to 1,500,000 gallons in ordinary weather, and is of a domestic character. The total expenditure per week for labour and materials in purifying the sewage, and converting the sludge into cement, is stated to be 35*l.* The total resulting cement averages 15 tons a week, and the value claimed for it is 40*s.* a ton. This system of dealing with sludge accomplishes the very desirable result of getting rid of it quickly and without nuisance, but it is not yet clear to the author that it is the best way commercially, inasmuch as it is stated by Mr. Granville Cole, who is familiar with the process, that the manufacture of Portland cement from sludge is much more precarious than when made in the ordinary way.

The precipitation process used at Coventry consists in the addition of a proto-sulphate of iron to a sulphate of alumina with a small quantity of lime, the effluent water being filtered through 9 acres of land. The population is 41,000. The number of water-closets connected with the sewers is 5500.

The daily flow of sewage is 2,250,000 gallons, and is of a manufacturing character, containing dye refuse. The Town Council have leased their works to the Rivers Purification Association for an annual subsidy of 2200*l.*, the cost being understood to be about 2000*l.* The quantity of manure produced, containing 50 per cent. of moisture, amounts to about 5 tons per day, or 2½ cwt. per 1000 persons.

The A B C, or native guano process, employs as precipitants alum, blood, clay, and charcoal. It is now in operation at Aylesbury, a town of 7200 inhabitants, where the ordinary flow is about 300,000 gallons a day of domestic sewage, which is increased in wet weather. The cost of chemicals and labour is 2162*l.* per annum. The quantity of sludge containing 90 per cent. of moisture obtained in twenty-four hours at these works is 20 tons, equal to 140 tons per week, or 7280 tons per annum, or about 1500 tons containing 50 per cent. of moisture, or 11½ cwt. per 1000 people, the sludge containing 50 per cent. of moisture. This, when dried, produces 845 tons of native guano per annum, containing 14 per cent. of moisture, or rather over 2¼ tons a day. The total cost of a ton of finished native guano is stated to be 2*l.* 12*s.* 8*d.*, and the value claimed for the manure dried to 14 per cent. of moisture is 3*l.* 10*s.* per ton. No land is used to filter the effluent. There are other chemical processes which have either become obsolete, or to which allusion is not necessary.

Where a high standard of purity is required, chemical treatment requires to be supplemented by filtration of the effluent through a small area of land to remove the organic impurity which remains in solution, and which in the best systems is about 1·50 part of albumenoid ammonia in 100,000 parts. An effluent containing only this is sufficiently pure to be admissible under many circumstances. Where a small area of land can be obtained as an adjunct to a precipitation works, the author always advises its acquisition. In arranging works for the purification of sewage too much expense has frequently been incurred, either through want of experience on the part of those engaged in laying out the works, or in consequence of the works being too elaborate. Simple works can be constructed to effect the precipitation of sewage for about 6*d.* a head of the population for interest on outlay, and an additional 6*d.* per head per annum for the cost of treatment with the most efficient chemicals and converting the sludge into manure. The value of the manure produced might in time pay a part of the cost if it is derived from a proper system.

The sludge produced by precipitation processes has a manurial

value dependent on the nature of the precipitants employed, but which with an efficient chemical process will produce a manure that is worth the farmer's while to apply to land, and even to pay a price for. This is stated to prevent its being regarded as a waste product utterly valueless. There are four methods now practically employed for dealing with sludge, viz. (1) By reducing it by exposure, or by means of presses, to a condition like stiff clay, containing about 50 per cent. of moisture, by which it can be carted from the point of production and applied to land. (2) By drying it to powder containing about 15 per cent. of moisture by artificial heat, as the Native Guano Company do. (3) By fortifying it with materials of a highly fertilizing value, with the view of ensuring its recognition as an artificial manure, such as is done at Wrexham. (4) By burning it into a cement, as is done by the Scott process.

Where a town is situated so as to enable its refuse to be cast into the sea without a costly outfall sewer, and at a point where there is a current seaward, much of the difficulty attending sewage disposal does not arise. Such a case is seldom, however, met with, although from want of careful tidal observations many seaside towns have thus disposed of their sewage, and have had it returned to them or their neighbours to prove that it was not so readily got rid of as was imagined.

In conclusion, the author would observe that each town must deal with its sewage difficulties in the way that is best suited to its circumstances after carefully considering the conditions which apply to the town, and that it is indispensably necessary for those who are called upon to advise in these cases not only to be free from bias in favour of any one system, but also to have a practical experience in the several ways of disposing of sewage. The adoption by a town of an unsuitable method of sewage disposal is, from a financial point of view, a step which is irretraceable.

DISCUSSION.

Mr. H. P. Stephenson said that some years ago he had something to do with farm sewage, in connection with Mr. Mechi and others who were interested in the question, and in that case the sewage was obtained from the stock and diluted to such an extent as made it fit for disposal upon the land. But in a town where they had all the surface water and a large quantity of subsoil water thrown into the sewers, there was so much water mixed with the sewage that it was not good for anything; and when sewage in such a state of dilution was thrown upon the farm the land was drowned, and bad results

ensued. He agreed with the author as to all the soil sewers being made watertight, and the subsoil water kept out of them. He thought that it would be very much better if as a rule they kept more of the surface and subsoil water out of the sewers than they did at present. He would even go to the extent of having independent sewers for the rain-water. He particularly noticed one expression which the author of the paper had used in speaking of the chemical processes that were adopted. He referred to the dry refuse having a value claimed for it. He (Mr. Stephenson) would like to know whether that was the value that was realized. As far as his knowledge went, the lime process and the A B C process had been complete failures. He believed that the solid particles taken out of sewage were of no commercial value whatever, and he should be surprised to learn from the author that the 240 or 250 tons a day of concentrated solids realized anything like the prices mentioned.

Mr. Shiress Will said he concurred with Mr. Robinson in the opinion that local authorities were not sufficiently awake to what their duties were in respect to the disposal of sewage, and he thought that they could all bear out, from their reading and experience, Mr. Robinson's statement as to the effect upon the public health of undisposed of sewage. He thought that local authorities had too often paid too much regard to the question of what they might obtain for the product of sewage when treated by chemical processes. He considered that local authorities would do well to remember that their first duty was to dispose of the sewage, and their second duty, if it ever arose, was to ask whether they could get a profit from doing their duty. They should regard the disposal of sewage in the same light as they did the carrying out of other useful sanitary measures. Those duties they could be compelled to perform whether it paid them to do so or not. With regard to the question of cost, it occurred to him that sometimes local authorities forgot that trying small schemes was, after all, a very expensive way of disposing of the sewage of every district. They could not do better than remember that the disposal of sewage was a matter which had been carefully studied by many practical engineers who were competent to advise them as to the best available means of disposal, whether the sewage was dealt with by irrigation, filtration, chemical treatment, or a combination of the different systems. These were matters upon which a local authority ought to be carefully advised, and he thought that the first cost of obtaining the advice from sound practical men who had had experience as engineers and sur-

veyors would not be thrown away, and ought to be regarded as a good expenditure. It was sometimes said that a provisional order occasionally entailed undue cost, and that the Confirmation Bill might be opposed both before the House of Commons and before the House of Lords. That fact only showed the desirability of local bodies taking proper advice to begin with. They might depend upon it that Parliament would further their efforts if they went before the House or before the Local Government Board with a properly prepared and carefully considered scheme.

Mr. Baldwin Latham said that some of the points which had been touched upon by the author were very much open to question. It was most unfortunate that the author should have selected London as a typical place suffering from bad drainage, for London happened to be the healthiest city in the world; and with regard to specific diseases, such as typhoid fever, London had the lowest death rate from that disease of any town in the kingdom, notwithstanding the defective sewers and foul water system of which the paper made mention. A large number of diseases had been classified by the author of the paper as being capable of production by sewer air, and amongst them typhoid fever. He (Mr. Latham) believed that the highest authorities of the present day were beginning to admit that typhoid fever, which had been ascribed to sewer air, was very rarely produced by that means. Dr. Maclagan, in his work upon the 'Germ Theory of Disease,' had pointed out that in order to produce a particular disease the poison of that disease must be carried to its nidus. The nidus of typhoid fever was confined to a short length of the lower intestines, and this author further pointed out that the chances were a thousand to one against a typhoid germ which entered the human system by the respiratory process being carried by the circulation, which was the only way it could go to the minute blood-vessels of that particular part in which was situated the nidus of the disease. When typhoid became epidemic it would be found that the poison of the disease was carried either in food, or water, or milk, or some article which at once conveyed it direct to its nidus. That was one of the modern discoveries which rather tended to show sanitary engineers that when they had to deal with outbreaks of typhoid they must not be content with ascribing the cause to the discovery of an unventilated sewer or house drain, but look for other causes if a permanent remedy was to be secured. It might be taken for granted that sewer air was dangerous, but it was not that great bugbear that it had been made to appear. A great sanitary danger had been

created in the belief in the potency of sewer air to cause all manner of diseases, and the consequence had been that disease had been ascribed to its presence which further investigation would have shown was due to other causes. Another point touched upon in the paper was the question of fœcal separation. Of course where fœcal separation took place it did not obviate at all the necessity of sewers. Where sewers were defective it was probably desirable, so far as the health of the town was concerned, that fœcal matter should be kept out of the sewers, because experience had demonstrated that fœcal matter, especially in typhoid fever, carried with it the poison of the disease, and as long as fœcal matter was kept out of ill-constructed sewers the danger of propagating that particular disease might to a great extent be avoided, especially in cases where local well water was in use. But a sewer ought to be as perfectly water-tight as a water-main, so that not one drop of water should be allowed to leak out of it, or one drop of subsoil water be allowed to enter it. As long as there was an interchange of water between the sewers and the subsoil there would be a danger of the underground streams upon which our houses were built being fouled, and a train of evils necessarily followed. The author had mentioned a danger which if he had had any practical experience in the management of sewers in towns he would have seen could not possibly happen. He said that where a duplicate system of sewers existed there was a danger that the workmen would connect the house drain with the wrong sewer. But under the Public Health Act all the sewers were vested in the sanitary authority, and no person had any right or power to touch a sewer except through the recognized officer of the sanitary authority. Proper plans of the systems of sewers should always be prepared, and reference to them would prevent such blunders as had been mentioned. Moreover, it must not be forgotten that the surface water drains were usually laid at a much shallower depth than the sewers, and in ninety-nine cases out of a hundred they would not serve for the proper drainage of houses, even if a connection were made with them.

As to the subject of the paper—the disposal of sewage—he was quite aware that that was a very vexed question. It had occupied his father before him, and it had occupied him (Mr. Baldwin Latham) all his lifetime, and the longer he lived the more strongly he was coming to the opinion that sewage itself had no great value. The cost of realizing whatever valuable products it contained would generally equal the value of those products. During the past year he had acted as one of the

judges for the Royal Agricultural Society in awarding the prizes which had been offered by the Mansion House Committee for the best managed sewage farms and works in this country, and in company with his colleagues, Mr. Clare Sewell Read, M.P., and Mr. Thursfield, he had made an inspection of a large number of farms throughout the country. They had been able to overhaul the whole of the accounts of those farms for some years back, and he could say that in a great number of cases an absolute profit was made. He would mention one case, that of Leamington, where the sewage was pumped. The authorities of Leamington had tried by means of chemical processes to solve the question of purifying the sewage, but, like other places, the more money they spent upon deodorizing, the greater the difficulties they met with, until the Court of Chancery compelled them to remove the sewage from the river. The result of that had been that the Earl of Warwick came to their rescue, and gave them 450*l.* a year for the sewage, on the condition that they would pump it upon one of his farms. The balance-sheets of that farm for the last three years showed that it had not only paid the rent which was charged to the farm before the sewage was taken to it, but it had paid the 450*l.* a year for the sewage. On an average it had also paid 4½ per cent. per annum during the last three years upon the 15,000*l.* which had been expended in laying out, stocking, and preparing the land for the reception of the sewage, and the erection of farm buildings and other improvements, but in this case the town got no return. They received 450*l.* per annum for the sewage when pumped, but the annual cost of pumping was about double the amount they received. This was an instance of a successful mode of getting rid of a nuisance, at not a very great outlay, as the effluent passing from the farm was always extremely satisfactory. This effluent ran into a very small brook, the water of which was always clear and pellucid.

There were other examples throughout the country showing that wherever sewage was applied to the land, the difficulty of disposing of it was invariably got rid of. Unfortunately, the nuisance had not always been got rid of in cases in which precipitation had been carried out. It was often the fact that the more money that was spent upon chemicals for precipitation, the worse the sewage became, and the worse became the condition of the river into which it flowed. While fish could feed upon fresh sewage, they had a strong objection to chemicals, and especially to those connected with any lime process. The bad result of chemical treatment was shown in the case of Croydon, until the Court of Chancery compelled the Croydon

authorities to take their sewage out of the river and apply it to land. If the Croydon Local Board had been wise enough in the first instance to have purchased the land which they required, they would have been at the present time making a very large profit. At the time they commenced irrigation the land which they required was sold for 80*l.* an acre, but now they had to pay 250*l.* an acre for it, and of course it was utterly impossible for any agriculturist to make land pay when he had to pay that price for it. If land could be got at its ordinary normal value it would under sewage farming give such a return as would pay its way, with a fair return on the capital embarked, and he did not think that anything more could be expected. At Guisborough in Yorkshire, a place containing 5300 people, Admiral Chaloner gave the town 5*l.* a year for the sewage. The sewage flowed by gravitation on to the land, and the farm was charged with 5 per cent. upon the outlay, and after all these charges a profit resulted. In the case of a sewage farm company that worked the Croydon farm for some time, and with which he and Mr. Alfred Williams were connected, they had to pay 10*l.* an acre rent for the sewaged land, and they had to pay the interest upon the outlay for the works, and, of course, in a few years the company came to grief and was wound up. But if they could have had the land at its normal agricultural value, or even at 5*l.* an acre, the company would have been in existence still, and making a very fair profit. He was now coming to the conclusion that the question whether sewage farming paid or not was entirely a question of rent. The universal cry of agriculturists at the present day was for a lowering of rents; in the case of sewage farms a lowering of rents was desirable. The case of Wrexham had been referred to. In that instance Colonel Jones paid 5*l.* an acre rent, and yet he was able to show a profit during the whole period that he had managed his farm of 104 acres. That farm had been referred to as an instance of precipitation, but it was not an example of that process. At Wrexham the sewage was allowed to pass into subsiding tanks just in the same way as in any other sewage farm. The sludge was removed by simple subsidence without the aid of any chemicals, and after being dried, about 12 cwt. of the sludge was mixed with bone meal and sulphate of ammonia to bring up the total quantity to a ton. This mixture was sold at 6*l.* a ton, under the name of "The Farmer's Friend." But he thought that Colonel Jones would have been a much greater friend to the farmer if he had given him a ton of bone meal and sulphate of ammonia without the sludge. With regard to precipitation,

his (Mr. Latham's) experience had been most unfortunate in connection with companies for carrying out precipitation processes. But he was not going to decry the value of precipitating processes, for no doubt in some cases they were invaluable. Those who brought them forward were entitled to every consideration, and he trusted that some day they might succeed in finding the philosopher's stone by which they would at once extract the valuable product from the sewage, so that they might be able to discard the dross and retain the gold. He was sure, however, that that day was very distant. The very first principles of chemistry taught them that the great point of value in sewage was the ammonia, which was more soluble in water than anything else. But in order to separate it from water it must be rendered insoluble. Now supposing that they did discover a process by which the ammonia could be made insoluble and so separated, ammonia in that insoluble condition would be of no value whatever, unless it could again be brought by another process into a soluble condition for the food of plants. Hence the very idea of removing the valuable principle in sewage by precipitation was a delusion. Some years ago he made a very large number of experiments in precipitating by means of various agents, and he found that the best precipitating material—one which General Scott had revived again last week—was the sewage sludge itself. This sludge contained organic matter which might be said to represent carbon. It also contained a certain amount of alumina, phosphoric acid, and slight traces of iron, all of which had been used for precipitating. If they charred this sludge after drying it, collected the ammonia, and afterwards treated the charred matter with acids, they would obtain a precipitating substance which contained no foreign matter, and by means of this substance they would be able at once to precipitate that part of the sewage which was most offensive. They must take care that the prepared sludge did not contain more acid than the alkalinity of the sewage would neutralize. The first part of the process of treating the sewage might be carried out in the first divisions of the tanks, and then if alumina and lime were added in other divisions of the tanks a very good effluent would be produced, and a manure of some value be secured. Although there was much prejudice against precipitating processes, he knew that many of them had done great things. The A B C Company's process at Aylesbury, if properly worked, turned out remarkably good effluent, and he had seen with great pleasure that the sewage-carriers flowing from the tanks at Aylesbury had actually shown a green vegetation at the bottom—a thing which never

took place unless the most deleterious portions of the sewage had been removed. There were other cases in which precipitation was applied successfully, as at Coventry, under the Rivers Purification Association. The selection of a process for treating sewage resolved itself very much into a question of what was expedient rather than a question of cost. There was no doubt that where land could be obtained, the land process was the most easy to deal with. There were immense difficulties in dealing with chemical processes, and perhaps the most difficult of all was the want of uniformity in the flow of the sewage, and the consequent variations in the proportion of the quantity of the chemicals to the quantity of the sewage, which variations in the end gave rise to a turbid effluent. Those who had had the slightest experience of sewage farms knew that the effluents from irrigation were always satisfactory, and that it required no very great amount of attention or skill to conduct a sewage farm so that it should not be a nuisance; but with a chemical process constant attention by day and night was necessary, for a moment's neglect might be attended with disastrous consequences.

Mr. Eachus stated, with reference to the low standard of mortality which had been remarked upon in London, that it was also to be found under widely different conditions with regard to sewerage. No doubt the comparative freedom of the London sewers from sewer gas was due to the continuous and uniform flow of sewage in the sewers, which tended more than anything else to keep down the production of sewer gas in the sewers, and consequently in the houses also. He cited as an opposite extreme the case of a Polish village consisting of some 300 or 400 houses surrounding a large square, the closet arrangements consisting of the primitive pail with or without a cover, the disposal being equally primitive, as the pails were simply emptied periodically in the square; and yet even under these filthy conditions there was said to be a very low rate of mortality. Somewhat similiar conditions were found in some of our own old-fashioned farmsteads; the fact was that the most essential part, the house itself, was kept free from noxious gases, and there was an abundant supply of fresh air outside. With regard to the general disposal of sewage, that was very much governed by the *locale* and the quantity and price of land. If sufficient land could be obtained irrigation was no doubt the best system, but there were conditions under which it was necessary to adopt chemical processes; that was especially the case with comparatively large populations, scarcity of land, and no lack of money. He (Mr. Eachus) did not experience the

difficulty, suggested by Mr. Latham, of apportioning the quantity of chemicals to the varying flow of the sewage; that he generally effected by storing the sewage and pumping from the reservoir for the required number of hours at a uniform rate, and of course a similar arrangement would apply where the discharge was by gravitation. In the case of smaller towns or villages, so situated as not to be able to adopt irrigation, he thought that simple subsidence would be sufficient, especially if the discharge took place into a sufficient stream of water, and he quite agreed with Mr. Latham that under such conditions less harm would be done by the effluent than if lime and other chemicals were used.

Mr. Perry F. Nursey observed that a system of sewerage plant and apparatus which had been invented by Mr. Isaac Shone, of Wrexham, had recently come under his notice, and it might prove of interest to the members to know something of its general principles. Mr. Shone's system was designed for use in flat districts where gravitation could not conveniently be resorted to. He proposed to have a central engine station, where he would establish powerful air-compressing apparatus, and from which point the compressed air would be delivered at sewage collecting and lifting centres. At each of these centres there would be an ejector, which would consist of a chamber into which the sewage should flow by gravitation. When the sewage had reached a given level it would open a valve, and the compressed air would be automatically admitted into the chamber upon the surface of the sewage, which it would force out to its destination. When the contents of the chamber had been discharged the air would escape by a valve, and a fresh charge of sewage would enter, to be dealt with in a similar manner to the previous one. According to Mr. Shone's designs the whole arrangement was automatic. He (Mr. Nursey) understood that the system had been applied to a limited extent in Wrexham, but he was not able to place before the meeting particulars as to the cost and results of working.

Mr. Brooking said that as a public surveyor he was unable to agree with the author on the subject of laying the surface-water drain and the soil sewer in the same trench, for in his opinion such a course would scarcely be practicable. It was well known that soil sewers must often be laid at a very great depth, and if the road-water drain was laid in the same trench there would be greater difficulty in forming connections, and the road-water drain would often have to be taken some distance farther than it would be necessary otherwise to take it, especially in suburban districts. With regard to the statement that sanitary authorities

discouraged drains and water-closets being connected with the sewers, he must say, from ten years' experience of working with sanitary authorities, that his observations did not bear out the author's remarks. In fact he found that they were most anxious (in and around the metropolis) to get all houses properly connected. He knew of no sanitary authority which had not got rules which must be obeyed before any connection was made with their sewer, and he considered the separate system a desirable one in many places, though he scarcely thought it possible that the drain of a house could unintentionally be connected with a road-water drain in lieu of the sewer. He agreed with the author that it was very desirable that all sewers and drains should be thoroughly ventilated. He often wondered how it was that the metropolis was so healthy, seeing how few of the drains were ventilated. Though he had been in many towns in England he knew of no place where so few of the sewers and drains were ventilated as in London, for as to house drains he did not think there was ten per cent. of them ventilated. It had often occurred to him that the health of the metropolis was greatly benefited by not having a separate system of sewers, for the copious and continuous discharge of water and the periodical flushings were certainly conducive to health, whilst the large amount of road detritus which was so frequently washed from the streets of London into the sewers acted as a precipitant, and also to a great extent as a deodorant. And it was a matter of doubt to him whether London would continue to be as healthy as it was at present if it ever became necessary to have a separate system of drains and sewers.

Mr. Robinson, in reply, said that one part of his paper seemed to have been taken hold of in a way for which there was no necessity. He described the separate system as a means of simplifying the disposing of sewage in some cases, but he did not allude to it in the way of advocacy. And as to the use of the same trench for the surface-water drain and for the sewer, the paper merely stated the fact that both were sometimes laid in the same trench. With reference to that part of the paper which stated that there was a fear of confusion between the two drains, he thought that he might claim to be on better ground than Mr. Baldwin Latham, considering that he (Mr. Robinson) had taken for his authority no less a man than Mr. Rawlinson himself. He begged to differ, with very great regret, from those persons who thought that house drains were laid with extreme care and that the surveyor examined them as they ought to be examined. He ventured to say that a surveyor would tell them that if he had to look at all the house connections it

would require him to be, like the Irishman's bird, in three places at the same time. Last year he was engaged with an officer of the Local Government Board in an inquiry as to an outbreak of diphtheria in the metropolis, and it was his duty during that inquiry to look very closely into the question of how the house drains had been connected, and he could tell them as a fact that there was not one case in a thousand where any observation whatever had been made as to whether the house drains had been put in right side up or wrong side up. He said with regret and shame that the utmost neglect had existed. It was imperative that a surveyor should be supported very strongly by his vestry in order to enable him to ensure the house drains being laid as perfectly as they ought to be. With regard to the medical aspect of the case, it had been stated that typhoid fever was not due to sewer gas. He was not concerned about the precise forms of disease that sewer gas produced, suffice it to say that diseases of some kind were produced which should be considered as preventable, but whether in the exact forms which he had described he would leave to others to determine. He (Mr. Robinson) had not referred to the death rate of London for the purpose of showing that London was not a very healthy town, but it would probably be remembered that it had been recently stated most distinctly by a deputation headed by Cardinal Manning, and consisting of other persons of eminence, that there was a large amount of typhoid and similar illness in the metropolis caused by impure water, and that the death rate was probably two in a thousand higher than it ought to be in consequence of the foul condition of the water supplied to the metropolis. He had not urged in the paper that the sewerage system of London was defective, but on the contrary, in one part of his paper he recognized the fact that the Metropolitan Board of Works had given London an excellent system of sewers. What he had wanted to make them understand was that the excessive death rate was due, not to bad sewerage, but to collections of foul matter in places where they ought not to be allowed. In the metropolis, as everywhere else, there was a want of proper supervision of the receptacles for the water (where the service was not constant). The cisterns were not cleaned out often enough, and it sometimes happened that if green slime or dead animals were present in the cisterns, they were only found after an outbreak of fever or some other mischief had occurred. It was his opinion that it was the duty of sanitary authorities to take care that accumulations of foul matter should not occur in cisterns. As to the question whether sewage should be

disposed of by chemical treatment or by irrigation, he had given some of the results of his own experience, but he had no system of his own to advocate. Each town must be dealt with according to its own circumstances. He agreed that purification by means of land was the best method where land could be obtained, but in other cases chemical treatment was necessary.

The PRESIDENT said they had been dealing with a subject about which the best authorities were at issue. He was not surprised that Mr. Robinson had taken London as an example, because, although, as Mr. Latham had said, the death rate of London was one of the lowest considering the population, it must be a marvel to all observers that the death rate of London was so low as it was in spite of all the wonderful disadvantages of which they had heard from time to time. It must be remembered that the authorities of London were at variance between themselves. The Board of Works was at issue with the Thames Conservators, and at the present time an exhaustive inquiry and arbitration on their dispute was going on in Westminster. The disposal of offensive matters was a question of going step by step to the right place in the right way. If each person in this country could deal with his sewage as the Chinese deal with theirs, by keeping it in a dry state and carrying it in a pail, and putting it into a little hole in the earth, and planting a tea-tree on the top, that would be a very happy state of things; but it would be a process which would be found exceedingly disagreeable and troublesome, and he would rather not be compelled by law to follow the example set in China. It had become indeed necessary that the offensive matter, which in a certain sense was intrinsically valuable, should be mixed with water, which cost but little, in order that it might be carried away from our houses and outside our towns and cities. Then arose the question as to where the duty of the engineer was to end and the work of the chemist was to begin. He thought that irrigation was the simplest way of dealing with the sewage, but if suitable land could not be obtained for that purpose, the next question was the provision of some other receptacle or treatment. There was no doubt that sewage was, as Lord Palmerston had said with reference to dirt, matter which was generally to be found in the wrong place. All the efforts of engineers should be directed to devise the means of taking it where it could be useful, with due regard to economy and sanitary results; but municipal or other local authorities must not let it be their chief aim to make the sewage of a town a source of profit. It fell to his lot about forty years ago to be a surveyor comparatively free from

control, and at that time he undertook to abolish some gutters in the middle of the streets of the town in which he was engaged, and for that purpose he put down sewers, but he would not allow anybody to connect a water-closet with those sewers, because he saw that such connections would spoil the river into which the sewer flowed. That work of his was done before public attention had been directed to the subject, and before there had been any squabbles with regard to discharging sewage into rivers in any town in England. He should stand out just as strongly now, and if he were an autocrat and ruled all London as he liked, he would not allow the sewage from water-closets to be discharged into the river Thames. Now there was a discussion about the sewage of London being discharged at Crossness and Barking Creek. He did not wonder at the Conservators of the Thames being miserable. Failing any other remedy he would make the Board of Works take the sewage down to Maplin Sands. He believed that there was a wonderful piece of country there, where the sewage of London would do good—a kind of desert which might be made to rejoice. It was our misfortune, as well as our happiness and our glory, that London was so big as it was. It was a misfortune as far as the sewage was concerned, for there was a vast volume of that matter which ought to be taken to some place where it would be less objectionable than it was at its present outfalls. There was one other point to which he would just refer. A great deal of money had been spent in connection with the sewage of Cheltenham, and of all the bad smelling places he had ever visited Cheltenham was about the worst. Nearly all the connections with the main sewer had a gaseous channel from the sewer into the house.

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